States
nent of
ure

Economic
Research
Service

Soil
Conservation
Service

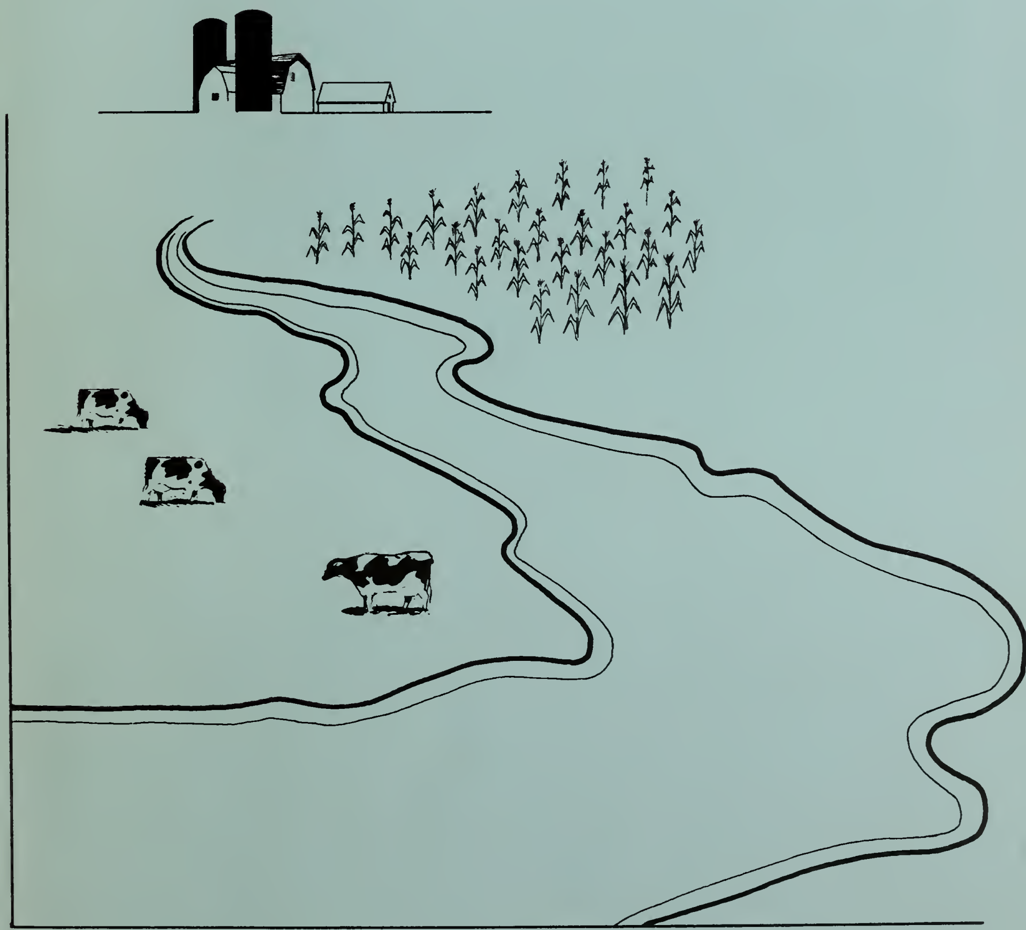
Forest
Service

in cooperation
with the

Massachusetts
Water Resources
Commission

August 1984

Massachusetts Agricultural Water Quality Study



MASSACHUSETTS AGRICULTURAL-WATER QUALITY STUDY

MAIN REPORT

&

APPENDIX A, Regional Problem Summary
APPENDIX B, Best Management Practices
APPENDIX C, Bibliography

MASSACHUSETTS RIVER BASIN PLANNING PROGRAM

U.S. Department of Agriculture
Soil Conservation Service
Economic Research Service
Forest Service

in cooperation with the

MASSACHUSETTS WATER RESOURCES COMMISSION

1984

Agricultural-Water Quality Study

Table of Contents

SUMMARY

In August 1979, the Massachusetts Department of Environmental Quality Engineering (DEQE) requested the Soil Conservation Service (SCS) to investigate agricultural operations and the resulting effects, if any, upon water quality in the state. The results of this investigation are reported here.

The approach of the study is as follows:

1. The entire state is screened to select those areas containing potential agriculturally induced water quality problems.

2. An analysis of potential phosphorus contribution to local water resources from agricultural land erosion and animal waste is conducted.

3. Twenty high priority and 25 priority problem watersheds were selected for technical assistance in solving agriculture-related water quality problems. Initiating appropriate agricultural and water quality programs in these watersheds is recommended.

4. Selection criteria of best management practices to reduce non-point agricultural pollution problems is discussed. See Appendix B, Best Management Practices.

5. A series of atlas maps showing agricultural land use, erosion rates on agricultural land and animal concentrations for selected cities and towns is provided. An example atlas sheet can be found in the back of this report.

Chapter 1. INTRODUCTION

In August 1979, the Massachusetts Department of Environmental Quality Engineering requested Soil Conservation Service (SCS) assistance to assess non-point agricultural water pollution problems in Massachusetts and to develop alternative solutions to identified problems.

The study was conducted under authority of Section 6, Public Law 83-566 and was carried out with the cooperation of the Economic Research Service (ERS), Forest Service (FS), Massachusetts Water Resources Commission (WRC), Massachusetts Department of Environmental Quality Engineering (DEQE), and members of the State Rural Clean Water Committee; Agricultural Stabilization and Conservation Service (ASCS), Massachusetts Association of Conservation Districts (MACD), Extension Service (ES), Farmers' Home Administration (FmHA), Environmental Protection Agency (EPA), Massachusetts Division of Conservation Services (DCS), and Massachusetts Agricultural Experiment Station (MAES).

A Plan of Study, Supplement 3 to the Massachusetts River Basin Planning Program Plan of Work, provided guidance and management to this effort.

Results of this study are:

1. An inventory and mapping of potential agricultural water pollution source problem areas.

2. The development of program strategies and recommendations for management systems to prevent and correct identified problems.

3. The identification of priority areas for detailed studies and treatment.

The structure of this report is as follows:

The Main Report states the problems and objectives of the study, suggests priorities, makes recommendations, and discusses implementation of programs which can improve water quality problems stemming from agriculture.

Appendix A, Regional Problem Area Summary, presents the technical analysis produced in the study. The selection process used to determine the final study area is presented in Chapters A2 and A3. Chapters A5 through A9, identical in format, each cover a reporting area or region which has a significant agricultural base which impacts on water quality. It is thought that many readers would be interested in only one or two of these reporting areas and would not want to read all five chapters. Chapter A10, Conservation Planning, discusses conservation activities in the state. Fertilizer and pesticide use is discussed in Chapters A11 and A12. Chapter 13 is a reprinting of Working Paper #3, Erosion Estimates on Agricultural Land, November 1981, which presents the methodology used to estimate the phosphorus loss associated with erosion from agricultural land.

Appendix B, Best Management Practices, lists the Best Management Practices suggested for Massachusetts by this study.

Appendix C is a bibliography.

Chapter 2. PROBLEMS AND OBJECTIVES

2.1. PROBLEMS

At the onset of this study it was suspected that agriculture could be adversely affecting water quality in Massachusetts. As presented in section 3.1.1, certain of the 208 studies, particularly those with significant amounts of agriculture in their planning areas, developed information documenting impacts on water quality from non-point agricultural sources.

This study was initiated because of insufficient information on the impact of the state's agriculture on the quality of the state's water resources. Along with the general need for more information on the impact on water quality there was a specific need for a systematic statewide assessment of the impact of agriculture on water quality in Massachusetts.

While this study was underway, two additional efforts to solve water quality problems, stemming in part from agricultural operations, were ongoing. The following discussion documents the impacts that non-point agricultural sources have had on the state's water resources.

Examples of water quality implementation programs in Massachusetts in which there is significant agricultural contribution to water quality problems include the Westport River Rural Clean Water Program Project and the Lake Lashaway Clean Lakes Project.

The U.S. Secretary of Agriculture selected the Westport River Watershed for the Rural Clean Water Program in June 1981. Projects selected for this experimental program have serious water quality problems due to pollution from agricultural sources. Shellfish beds in the tidal estuary of the Westport River have been closed for shellfish harvesting because of bacterial pollution. Dairy and other livestock operations are suspected to be major sources of the excessive numbers of coliform bacteria found in certain of the shellfish beds of the estuary. There are other sources of this pollution, such as on-site septic systems, but the impact of agricultural operations on the water quality of the estuary is estimated to be significant. The 1981 Plan of Work for this project states:

> "The Westport River is said to have serious point and non-point source pollution problems emanating from agricultural runoff which contains dissolved solids, bacteria, sediments, nutrients, and pesticides. ....
>
> The Massachusetts Department of Environmental Quality Engineering has monitored water quality and rainfall in the project area, and will continue to do so during the project term. Agriculturally related pollution of the Westport River appears to come from two main sources: Either animal waste or runoff containing residues of fertilizers and pesticides. The result of the water quality tests indicate that the major source of bacterial contamination to the east branch of the Westport River is the result of runoff from agricultural activities because of the size of farms and their location in relation to water sources." [1/]

1/ Westport River RCWP Project, Local Coordinating Committee, Rural Clean Water Program, Westport River Watershed Project, Westport, Massachusetts, Plan of Work - 1981, p. 6.

A plan for this project has been developed which calls for the expenditure of approximately $800,000 of federal and local funds for the installation of Best Management Practices on the farms in the project area. This project is administered by a Local Coordinating Committee comprised of representatives of local, state, and federal agencies. The Agricultural Stabilization and Conservation Service is the lead agency for the USDA in this project.

A Clean Lakes Program has been approved by the U.S. Environmental Protection Agency (EPA) for Lake Lashaway in the towns of North Brookfield and East Brookfield, Massachusetts. These programs are authorized by Section 314 of the Federal Water Pollution Control Act, Public Law 92-500, and subsequent federal clean water legislation and by the comparable Massachusetts legislation, Chapter 628, Acts of 1981, Massachusetts Clean Lakes and Great Ponds Program.

The Lake Lashaway Clean Lakes Program has been spearheaded by the Lake Lashaway Community Association working closely with the town governments of both East Brookfield and North Brookfield. The Massachusetts Division of Water Pollution Control has played a major part in this project as has EPA. One of the first actions of this project was to commission a comprehensive study of Lake Lashaway and its watershed by the consulting firm of Lycott Environmental Research, Inc.

Lake Lashaway has an aquatic weed problem typical of a highly eutrophic lake. An annual phosphorus budget was estimated for this lake. Once the relative amounts of the various phosphorus sources are known, then meaningful solutions can be developed to reduce or manage the phosphorus delivered to the lake. For most lakes in the region, it is assumed that phosphorus is the primary limiting nutrient and is the most appropriate nutrient to manage for control of plant growth. In this phosphorus budget, agricultural sources are estimated to contribute approximately 20 percent of the total annual input. Slightly over 50 percent of the total phosphorus budget is estimated to come from septic systems, primarily from the cottages and homes adjacent to the lake. [1/]

A pond drain has recently been constructed to allow lowering of lake water levels in the winter in order to manage and control aquatic plant growth. At the present time there is an opportunity to reduce nutrient and other pollutant discharge from farming operations in the watershed. Many of the Best Management Practices which are most appropriate for watershed farms are costly and presently available cost-sharing moneys for conservation practices have not provided enough incentive for practice implementation.

In general, more water quality problems stemming from agricultural sources in lakes and ponds are expected than from flowing water regimes, rivers and streams, and in tidal areas. The reasons for this include:

1. Location of agriculture. There are few coastal areas in Massachusetts which have such a concentration of agriculture as does the Westport area. Much of the coastal area is highly urbanized and the remaining coastal area has little or no agriculture.

1/ Lycott Environmental Research, Inc., A Comprehensive Eutrophication Study of Lake Lashaway, East and North Brookfield, Massachusetts, prepared for East Brookfield Conservation Commission and North Brookfield Conservation Commission, Southbridge, MA.

2. Lakes and ponds, or flat water, are usually more sensitive to a given level of pollutants than running waters. This is particularly so for nutrients.

2.2. STUDY OBJECTIVE

Study objectives include the evaluation of the effect of agriculture on the quality of the state's water resources. In addition, programs or other solutions will be recommended for problem areas. The first step in the evaluation process consists of the location and mapping of agriculture in Massachusetts, followed by screenings in which the more agricultural areas are selected. The evaluation process which follows is concentrated on these more agricultural areas.

2.3. LOCATION OF AGRICULTURE IN MASSACHUSETTS

Phase 1, Selection of Study Area, First Screening

The initial study area included all of Massachusetts. During this phase those cities or towns which have little to no agriculture were identified. Appendix Chapter A-2, Selection of Study Area, presents this process and Appendix Table A.2-2 lists the 174 cities and towns which did not meet selection criteria for further study.

Existing agriculture in these 174 deleted cities and towns could contribute to downstream water quality problems but it is generally not expected. In these cities and towns other non-point pollution sources are expected to overwhelm non-point agricultural sources of pollution. In the 1971-72 land use survey by MacConnell et al., 45 of these 174 cities and towns had less than 100 acres of agricultural land while the remainder all had less than 1000 acres of agricultural land. As with industrial operations where pollutants may be accidentally spilled, there is always the potential for accidental spills resulting in pollutants leaving a farm in these areas with little agriculture. Incidents of this sort are expected to be rare and because of the low density of agriculture in these areas can be considered as individual isolated events.

For the remaining 177 cities and towns (see Map A.2-1) recent agriculture land use data in both numerical and map form were needed. Also information on types, numbers, and location of livestock and poultry concentrations were needed.

Phase 2, Selection of Study Area, Second Screening

After agriculture was located in the 177 city and town study area the study concentrated on those 49 municipalities which were defined as the most agricultural in the state due to the number and concentration of agricultural operations. Only five of these selected cities and towns are not contiguous to one or more of the other selected cities and towns.

Phase 3, Identifying Potential Problems

In these 49 cities and towns the study analyzed potential water pollution problems stemming from:

1. Erosion on agricultural land

2. Use of fertilizer, biocides, and other agricultural chemicals

3. Animal waste

Estimates of sheet and rill erosion on all agricultural fields were needed to see what types of agricultural land had erosion problems, to learn how much erosion was actually occurring, and to analyze off-farm effects of this erosion. Erosion was not estimated on forest land on farms and on farmsteads as little erosion was expected to occur there.

In the 208 studies done in Massachusetts much concern was expressed about water quality problems caused by fertilizer and agricultural chemical use on farmland.

Estimates of animal waste quantities and information on animal waste disposal practices in Massachusetts were used to assess impacts on water quality.

Chapter 3. SELECTED PRACTICES AND RECOMMENDATIONS

3.1 BACKGROUND

3.1.1 208 Water Quality Management Plans

Under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), water quality management plans were developed for various regions of Massachusetts. In 1975, regional planning areas were designated by the Governor for 208 studies. These designated areas and the regional planning agency responsible were:

	Area	Number of Mass. Cities and Towns Included	Regional Planning Agency
1.	Boston Metropolitan Area	92	Metropolitan Area Planning Council
2.	Cape Cod	15	Cape Cod Planning and Economic Development Commission
3.	Martha's Vineyard	6	Martha's Vineyard Land and Water Commission
4.	Southern Worcester County	27	Central Mass. Regional Planning Commission
5.	Southeastern Massachusetts	29	Southeastern Regional Planning and Economic Development District
6.	Old Colony	10	Old Colony Planning Council
7.	Rhode Island	2	Rhode Island Statewide Planning Program
8.	Northern Middlesex	7	Northern Middlesex Area Commission
9.	Montachusetts-Nashua	14	Montachusetts Regional Planning Commission
10.	Upper Housatonic River	9	Berkshire County Regional Planning Commission
11.	Merrimack Valley	15	Merrimack Valley Planning Commission

These designated area 208 studies include 226 cities and towns or 64 percent of the state's total of 351 cities and towns. Water quality management plans are being prepared for the remainder of the state (the non-designated areas) by the Massachusetts Department of Environmental Quality Engineering. Examples of non-designated area plans completed include the Elizabeth Islands plan and the Ashburnham, Gardner, Hubbardston, Templeton, and Winchendon plan.

Some of the designated area plans did not consider agricultural non-point pollution in their non-point pollution analysis. As stated in the Metropolitan Water Quality Project report, "Agricultural runoff was not identified as an areawide problem and was not evaluated in the 208 program." 1/ This position is reasonable for the highly urban Boston metropolitan area which has severe point and non-point pollution problems and little or no agriculture. The Cape Cod plan states, "Due to the limited nature of agricultural land use on the Cape, the 208 water quality assessment did not specifically sample areas that may be affected by agricultural use...." 2/ and further recommends,

"1. Further water quality testing to determine the degree of the problem.

2. Use of best management practices (BMP's) to prevent development of water quality problems from these sources." 3/

Other plans list locations where agricultural operations are a suspected source of nutrients or other pollutants to ponds, streams, or other water resources. In addition, certain of these plans have presented recommendations for appropriate solutions or "best management practices" for reducing non-point pollution from agricultural operations.

The Montachusett-Nashua Areawide Water Quality Program report by the Montachusett Regional Planning Commission presents results from water quality testing of runoff from two orchards and one dairy farm. For the orchards, laboratory testing for pesticides presently used and for DDT and other pesticides used years ago failed to detect any of these pesticides in the water samples. Testing did indicate the presence of boron with sample values ranging from 0.00 to 0.18 parts per million. It was suspected that the boron originated from the application of pesticide which contained boron. 4/

Test results from sampling locations at one dairy farm indicate increases in nutrients and coliforms in a stream and pond downstream of the operation. 5/

1/ Metropolitan Area Planning Council, Draft Areawide Water Management Plan for the Metropolitan Boston Area, Volume III, Part 1, pp. 3-661, Boston, MA.

2/ Cape Cod Planning and Economic Development Commission, Water Quality Management Plan/EIS for Cape Cod, Volume 1, Barnstable, MA, Sept. 1978, p. 2-93.

3/ Ibid, p. 2-94.

4/ Montachusett Regional Planning Commission, Montachusett-Nashua Areawide Water Quality Management Program, Fitchburg, MA, January 1979, p. A-13.

5/ Ibid, p. A-20.

A major emphasis of the Water Quality Management Plan for the Upper Housatonic River was an analysis of the eutrophication 1/ of ten major recreational lakes in the region. This analysis included the identification of the major sources of phosphorus, and estimation of their contribution to the annual phosphorus budget of these lakes. Phosphorus is one of the major nutrients which contribute to excessive plant growth in lakes and to an acceleration of the aging process of these lakes. This process usually leads to a loss of recreational and other values of these water bodies. Erosion from cropland was a source of phosphorus for eight of the ten lakes while livestock was a phosphorus source for half of these lakes. 2/

Massachusetts DEQE's water quality management plans for the non-designated areas went into some detail for those areas which contained significant amounts of agriculture. The Water Quality Management Plan for Central Massachusetts (non-designated area), prepared by Massachusetts DEQE, analyzed water quality in 11 towns which are either partly or entirely in the Chicopee River Basin. This plan considered agricultural non-point sources because this area is one of the more important agricultural sub-regions of the state, with over 150 agricultural operations and 11,000 acres of agricultural land. Possible sources of non-point agricultural pollution include livestock and poultry manure and leachate from unsealed and uncovered silage storage pits. Other agricultural sources which were considered to be of lesser importance in this region include pesticides, herbicides, and fungicides on vegetable farms and orchards, and erosion from tilled areas. 3/

This plan by Massachusetts DEQE recommended that a further agricultural water quality study be performed by DEQE as a part of a statewide study. 4/ The Massachusetts AWQ Study is a response to this recommendation.

3.1.2 Present Agriculture-Water Quality Programs

USDA PROGRAMS

Conservation Operations. In Massachusetts, SCS works through 16 conservation districts which are subdivisions of state government. Landowners and users can become district cooperators and receive technical assistance in planning and applying conservation measures to their land. Most conservation measures have water quality benefits but certain measures such as Waste Management Systems, or Livestock Exclusion, can have major impacts on improving downstream water quality. See Appendix B, Best Management Practices, for the conservation measures selected for Massachusetts with the most potential for water quality improvements.

1/ The aging process in lakes which is accelerated by nutrient enrichment. Advanced eutrophication is noted by excessive algae and other plant growth in the lake.

2/ Berkshire County Regional Planning Commission, Water Quality Management Plan for the Upper Housatonic River Final Plan/Environmental Impact Statement, Pittsfield, MA, Sept. 1978.

3/ Massachusetts DEQE, Water Management Plan for Central Massachusetts (non-designated area), Boston, MA, December 1974, pp. 53-55.

4/ Ibid, p. 314.

Watershed Protection and Flood Prevention Act (Public Law 83-566). The SCS administers the watershed program which provides federal technical and financial assistance to state, communities, conservation districts, and others in solving land and water problems. Three purposes of importance in this act to our study concerns are:

1. Watershed Protection which is the protection of watershed area by reducing erosion, sediment, and runoff through the establishment of land treatment measures.
2. Conservation and Proper Utilization of Land which includes control of agriculture-related pollution through the application of conservation practices. Animal waste, agricultural chemicals, and pesticide runoff problems can be reduced under this purpose.
3. Agricultural Water Management which includes conservation, development, utilization, and disposal of water.

In this program a plan is developed for a watershed area, not to exceed 250,000 acres in size, to solve the identified problems. When a plan has been approved federal cost-sharing can be provided up to a limit of $100,000 to any one landowner or operator.

Resource Conservation and Development Program. There are two Resource Conservation and Development Areas (RC&D) in Massachusetts, the Berkshire-Pioneer RC&D Area which covers Berkshire, Hampden, Hampshire, and Franklin Counties, and The Pilgrim RC&D Area which includes Bristol, Plymouth, Barnstable, Dukes, and Nantucket Counties. Under this program where there is an authorized project area, projects similar to those described above under the Watershed Protection and Flood Prevention Act can be carried out. Usually these projects are smaller and less complex than those under the Watershed Protection and Flood Prevention Act. Assistance for installation of conservation measures under the RC&D program will be authorized only if offsite problems are solved. The SCS administers this program for USDA.

Agricultural Conservation Program. The Agricultural Stabilization and Conservation Service (ASCS) administers this program for USDA. Under this program cost-sharing funds are provided to farmers and other landowners who undertake soil and water, forest and wildlife conservation practices. Distribution of these funds is handled by county ASCS committees. Technical assistance on practices is furnished by the SCS, Extension Service, U.S. Forest Service, and the Massachusetts Division of Forests and Parks. Solving conservation and pollution problems is a major priority for this program.

Rural Clean Water Program. This is an experimental program administered for USDA by the ASCS. The purpose of this program is to reduce agricultural pollution of the nation's water resources. The program provides federal cost-sharing and technical assistance to encourage farmers to voluntarily perform Best Management Practices to control agricultural pollution. In Massachusetts only the Westport River is in this program. Up to $50,000 federal cost-sharing can be apportioned to an individual farm operation.

Agricultural Stabilization and Conservation Service Special Projects. Along with the above programs, ASCS also designates areas with agricultural related pollution problems as Special Projects. In designated Special Projects additional federal cost-sharing above the level of ACP funding can be made available for conservation and agricultural pollution control measures. The yearly maximum cost-sharing amount per farm for ACP of $3500 applies to these Special Projects.

Targeted Area Program

The Connecticut Valley Targeted Area program was recently approved for operations. This program is designed to accelerate technical and financial assistance to reduce soil erosion and water quality problems in this most agricultural portion of New England. The targeted area includes 19 counties within the states of Connecticut, Massachusetts, New Hampshire and Vermont. Agencies actively involved in this targeted area program include the SCS, ASCS, FmHA, Cooperative Extension Service, Massachusetts State Committee for Conservation of Soil, Water and Related Resources and similar state committees in the other three states, State Associations of Conservation Districts and the Conservation Districts.

A major impact of this program will be a reduction in adverse impacts from agriculture on water quality in the region. In addition, it is hoped that this program will add to the viability of agriculture in this four state area.

The Narragansett Bay Basin Targeted Area proposal, in Rhode Island and Massachusetts, has been submitted for approval. This proposal is similar to the Connecticut Valley program and will greatly lessen agricultural pollution in the Narragansett Bay drainage if implemented.

Other Federal Programs

Clean Lakes. U.S. Environmental Protection Agency. This program was authorized by Section 314 of the Federal Pollution Control Act, Public Law 92-500, and subsequent federal clean water legislation. This program focuses on lakes and their quality problems. Federal funds were available for diagnostic and planning studies and for lake restoration and protection implementation projects. At this time there are no federal funds for new projects; however, existing projects are still being funded.

State Programs

Clean Lakes and Great Ponds Program. Massachusetts Department of Environmental Quality Engineering. This program was established by state legislation, Chapter 628 of the Acts of 1981, the Massachusetts Clean Lakes and Great Ponds Program. When this program was established, the federal Clean Lakes Program was fully funded. At this time, the state program is the only Clean Lakes Program available for new projects in Massachusetts and is conducted by the Massachusetts Division of Water Pollution Control. Program funding is provided by the state for diagnostic-feasibility studies and for implementation of long-term restoration or preservation projects and for water quality maintenance programs which are conceived as short-term solutions for vegetation problems. Significant nutrient or other pollutants originating from agricultural operations could be identified in these studies.

Pesticides Program. Under state law, regulation of pesticides is carried out by the Pesticides Board which is within the Massachusetts Department of Food and Agriculture. Key functions of the Pesticides Program include:

Registration of pesticide products.

Certification and licensing of individuals as pesticide applicators, as supervisors of application of restricted pesticides, and as dealers in restricted pesticides.

Inspection and investigation of reported pesticide incidents.

Enforcement actions in incidents where violations occur.

At the national level, EPA is responsible for the administration of federal pesticide control legislation. A key function of EPA in this area is the regulation and control of pesticides for use nationwide.

The Massachusetts Cooperative Extension Service assists farmers and others with information on pesticide use including which pesticides to use and when, application rates, and other information necessary for proper pesticide use.

During the final review stages of this study, pesticide contamination of groundwater surfaced as one of the major water quality issues concerning agriculture in Massachusetts. As discussed in Appendix A, Chapter A12, Pesticides, monitoring for pesticides has been concentrated on surface waters in Massachusetts. Until recently, little monitoring of groundwater for pesticides has been done in the state. Now that recent monitoring of both private and public groundwater supplies has indicated pesticide contamination of many of these supplies many questions have arisen. Information is needed about which pesticides were used, the quantity used, the amounts which may still be in the local environment and other such questions about these pesticides. In addition, much information is needed about the specific groundwater aquifers affected and the transport mechanisms of pesticides and other contaminants from the site of application to and through these aquifers.

3.1.3 Mapping Program

In order to determine what effect agriculture has on water quality in the state it was necessary to develop a great deal of new information. Much of this information was mapped and included the location and extent of agricultural land in these categories - pasture, hay, cropland, orchards, nurseries, and cranberry bogs - for 177 cities and towns. For the most agricultural 49 cities and towns, erosion estimates were made for the agricultural lands listed above. Erosion estimates were not done for forest and idle lands on farms. All concentrations of poultry or livestock equal to 10 animal units or more in size were located in these 49 cities and towns also. See Table A.3-2 for breakdown of animal unit equivalents. (For example, a 1400 pound dairy cow equals 1.4 animal units while 250 chickens equal 1 animal unit.)

A mapping program utilizing 42 atlas sheets has been completed to show:

1. Agricultural land (pasture, hayland, row crops, orchards and plant nurseries) for 177 cities and towns.

2. Wetlands, major groundwater aquifers, streams, rivers, lakes, and ponds in these 177 cities and towns in order to show which water resources are likely to be impacted by agriculture.

3. Rates of sheet and rill erosion on agricultural land in 49 cities and towns selected as the most agricultural of the 177 cities and towns in Items 1 and 2.

4. Concentrations of livestock and poultry in these 49 cities and towns.

Prior to this study, the lack of the map information Items 1 to 4 was a handicap to a realistic assessment of the impact of agriculture on water quality in the state. At this time the SCS in Massachusetts plans to extend the sheet and rill erosion rate estimates on agricultural lands to an additional 108 cities and towns. These data along with those generated under Item 3 above, will indicate where there are concentrations of erosion problems and where our efforts should be focused.

The 42 map atlas sheets are reproduced at a scale of 1 to 50,000. The typical sheet is composed of four of the 7 1/2 minute U.S. Geological Survey Quadrangle Maps reduced to approximately half-size. There are 34 of the full-size typical sheets and an additional eight sheets which consist of either two or three quadrangle sheets only. See Map 3.1-1, Index of Agricultural-Water Quality Maps. There is an example of an atlas sheet in the back of this report.

3.2 Priority Areas for Agricultural Water Quality Programs

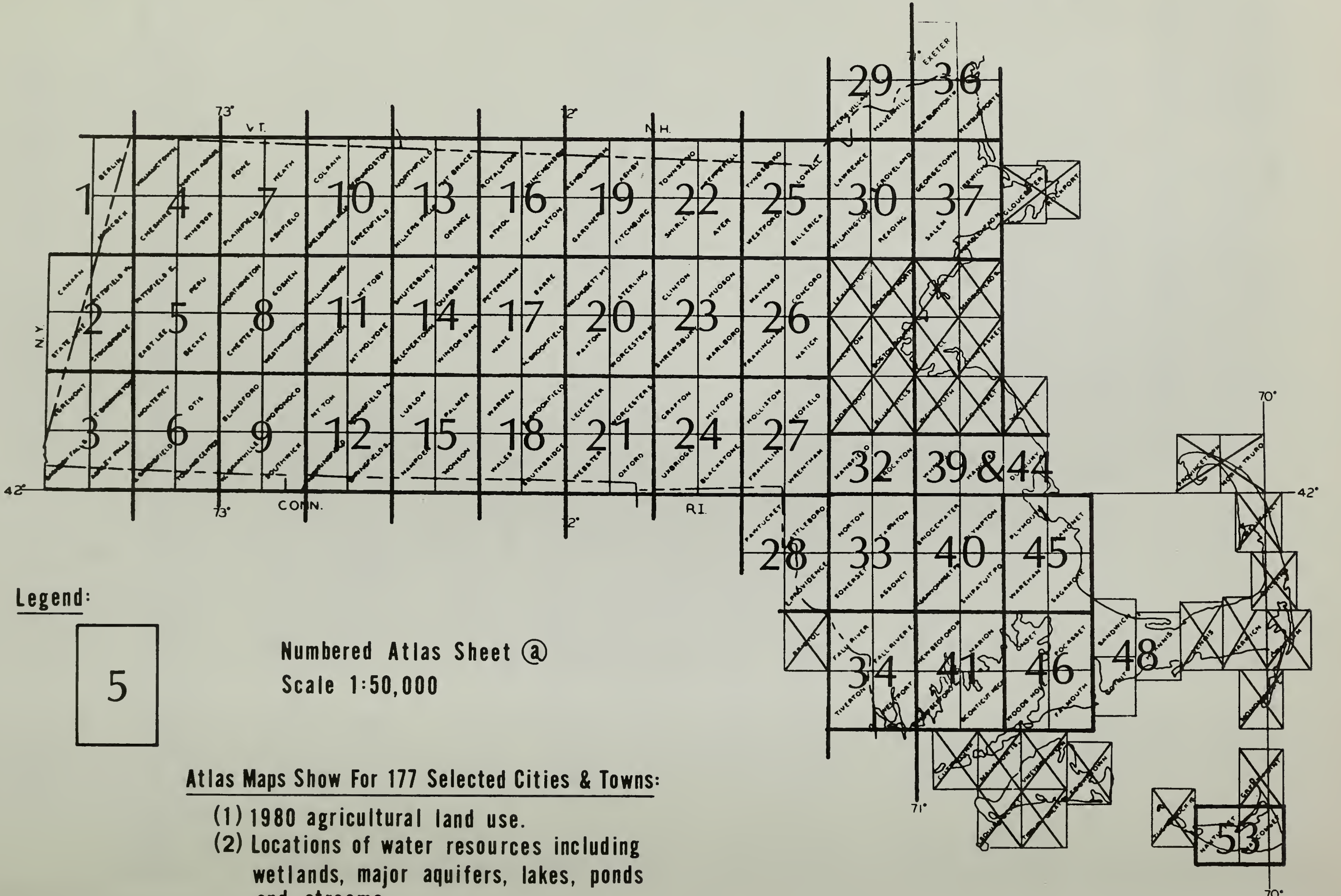
Using the agricultural land use and animal number data described in Section 3.1.3 and in Appendix A, a selection process was established to identify the 49 most agricultural towns and cities since it is expected that most water quality problems which arise from agriculture in Massachusetts would be located in these agricultural towns.

Estimates of the increase in yearly average phosphorus concentration in local water resources stemming from soil erosion and livestock waste were made. A threshold value of 0.010 mg. phosphorus per liter estimated average yearly concentration increase in a municipality's water resources was used as an indication of significant effect. As presented in the SCS publication, Agricultural Waste Management Field Manual, guideline values tied to eutrophication problems are 0.025 mg. P per liter for lakes and reservoirs, 0.05 mg. P per liter at confluences of small streams, and 0.10 mg. P per liter in larger streams. 1/ These are average or typical values and there are a great number of variables which can lower or raise these values. Other guideline values, in this case for lakes, are 0.010 and 0.020 mg. P per liter at spring

1/ USDA, Soil Conservation Service, Agricultural Waste Management Field Manual, Table 2-2, Tabular summary of numerical criteria. This information is based on recreational water criteria presented by the Environmental Protection Agency.

Figure 3.1-1

INDEX OF AGRICULTURAL WATER QUALITY MAPS



Legend:

5

Numbered Atlas Sheet @
Scale 1:50,000

Atlas Maps Show For 177 Selected Cities & Towns:

(1) 1980 agricultural land use.
(2) Locations of water resources including wetlands, major aquifers, lakes, ponds and streams.

turnover, with 0.010 being the boundary between oligotrophic and mesotrophic and 0.020 the boundary between mesotrophic and eutrophic conditions. 1/

In the 49 towns and cities analyzed, six cities and towns had estimated yearly phosphorus concentration increases of less than 0.010 mg. P per liter and were therefore dropped from further consideration. Fifteen towns had estimated average yearly phosphorus concentration increases of 0.025 mg. P per liter or more and watersheds containing sufficient portions of these towns were considered high priority watersheds. See Figure 3.2-1. Watersheds containing major portions of towns and cities with estimated increases of 0.010 to 0.024 mg. P per liter are considered priority watersheds for the:

1. Establishment of an agriculture water quality program; see those listed in Section 3.1.2. Under most of these programs a detailed analysis is done to determine the exact nature of the problem, its causes, alternate solutions, and the costs involved.

2. Establishment of a monitoring program to evaluate the water resources involved, streams, lakes, etc., to help determine nature of the problem(s).

Table 3.2-1 lists the high priority and priority watersheds considering agricultural non-point pollution and the resulting effect on water quality. These watersheds are also shown on Figure 3.2-2.

The priority and high priority classifications were based on an analysis of soil erosion and animal wastes. In those parts of the state where most of the cranberries are grown there are few, if any, water quality problems stemming from soil erosion and animal wastes. In Carver, the town with the greatest acreage of cranberry bogs in the state, there are few farm animals and almost no soil erosion on crop fields. This situation in Carver is typical for most of the major cranberry towns. Our erosion and animal waste analysis indicates that, in general, there are no excessive phosphorus loadings from erosion or animal waste in cranberry country. There still exists the possibility that agriculture may be contributing to water quality problems in cranberry country. The only potential pollution sources not discussed to any great extent are chemical fertilizers and pesticides. In Appendix A, Chapter A-11, Table A11-3 presents a quick and simplistic computation of potential increases in nitrogen and phosphorus concentrations in downstream water resources from fertilization of cranberry bogs. The resulting numbers indicate that nitrogen increases are minor, particularly in comparison to normally occurring nitrogen levels. The phosphorus values, however, are significant in the two towns with over 1500 acres of bogs in typical naturally occurring values. As mentioned above, this table is not based on a very rigorous analysis. However, the computed values for two towns suggest that further investigation is necessary. A major feature of any investigation should be a monitoring program designed to determine what materials are leaving the bogs and in what relative quantities.

1/ Vollenweider, R.A., W. Rast, and J. Kerelus, "Chapter 9, The Phosphorus Loading Concept and Great Lakes Eutrophication," Phosphorus Management Strategies for Lakes, Proceedings of the 1979 Conference at Cornell Univ., edited by Raymond C. Loehr, Colleen S. Martin, and Walter Rast, Ann Arbor Science Pub., Inc., Ann Arbor, Mich.

TABLE 3.2-1 - High Priority and Priority Watersheds for Agriculture Water Quality Programs in Massachusetts

Basin and [1/] WS WRC 8-Digit Code Number	Watersheds SCS 3-Digit Code Number and Name	High Priority	Priority	Watershed Includes These High Priority Towns	Plus These Priority Towns
Hoosic River 02020003	110 Hoosic R.	X		Adams, Cheshire	
	160 Hoosic R.	X		Adams	Williamstown
	150 Green R.		X		Williamstown
Housatonic River 01100005	140 Housatonic R.	X		Sheffield	Great Barrington, New Marlborough
	160 Hubbard Bk.	X		Sheffield	Great Barrington
	060 Housatonic R.		X		Lee, Great Barrington
	090 Housatonic R.		X		Lee, Great Barrington
	130 Green R.		X		Great Barrington
	170 Konkapot R.		X	Sheffield	New Marlborough, Great Barrington
	180 Blackberry R.		X		New Marlborough
Deerfield River 01080203	110 North R.	X		Colrain, Shelburne	
	120 Deerfield R.	X		Shelburne, Deerfield	Conway, Ashfield,
	130 Green R.	X		Colrain, Shelburne	Greenfield
Westfield River 080206	080 Munn Bk.	X		Southwick	
	100 Great Bk.	X		Southwick	
	010 Westfield R.		X		Cummington, Ashfield
Northern & Central Connecticut River Valley 01080201	120 Russellville Bk.	X		Deerfield, Hatfield, Hadley	Whately
	140 Mill R.	X		Hadley	Amherst
	150 Mill R.	X		Deerfield, Hatfield	Conway, Whately, Northampton
	160 Fort R.	X		Hadley	Amherst
	180 Broad Bk.	X		Easthampton	Southampton
	190 Manhan R.	X		Easthampton	Northampton, Southampton
	100 Pauchaug Bk.		X		Northfield
	170 Mill R.		X	Easthampton, Hatfield	Northampton, Ashfield, Conway, Whately
	200 Bachelor Bk.		X		Granby
	210 Stony Bk		X		Granby

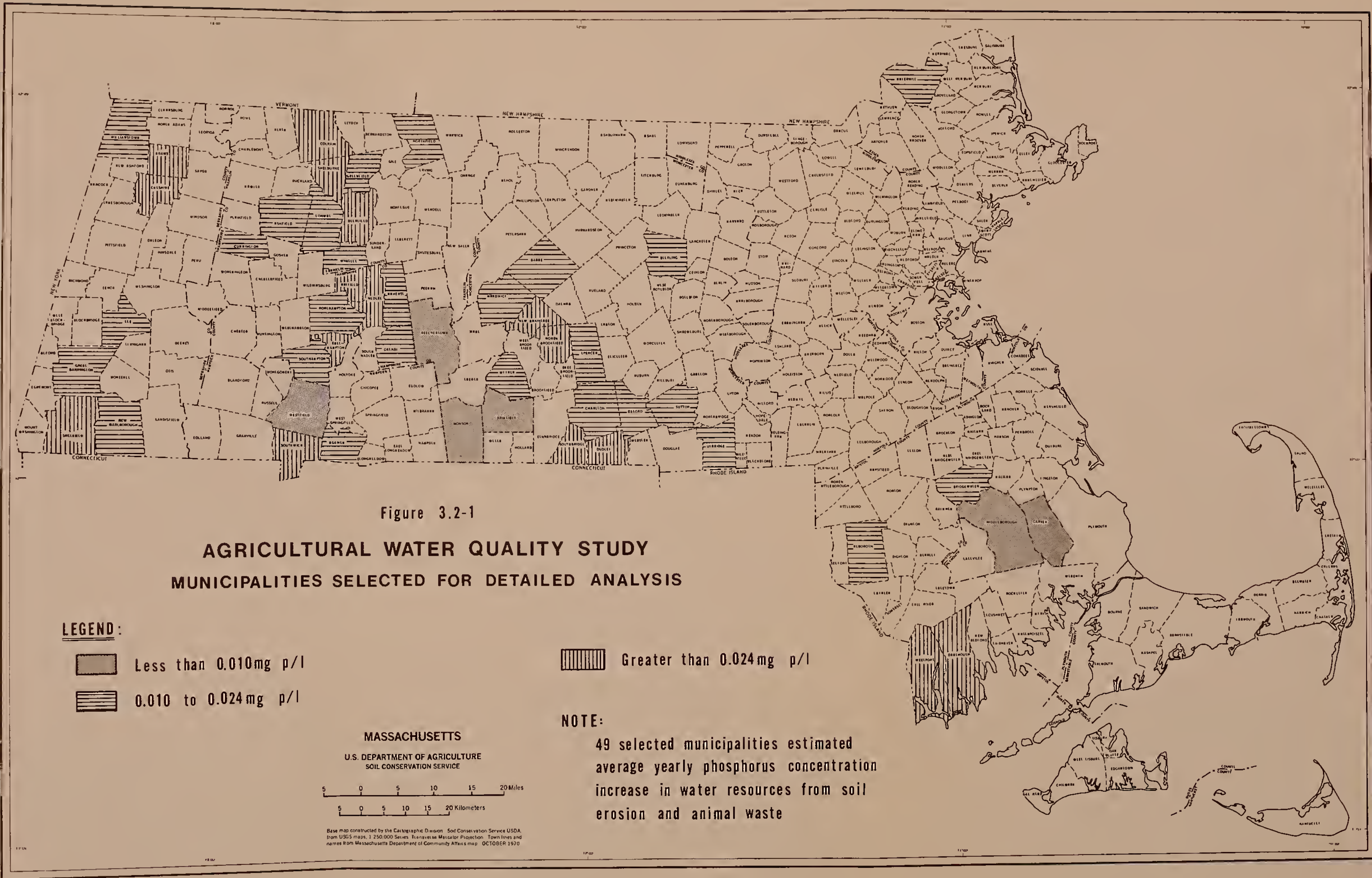


Figure 3.2-1

AGRICULTURAL WATER QUALITY STUDY

MUNICIPALITIES SELECTED FOR DETAILED ANALYSIS

LEGEND:

- Less than 0.010mg p/l
- 0.010 to 0.024mg p/l
- Greater than 0.024mg p/l

NOTE:

49 selected municipalities estimated average yearly phosphorus concentration increase in water resources from soil erosion and animal waste

MASSACHUSETTS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

5 0 5 10 15 20 Miles

5 0 5 10 15 20 Kilometers

Base map constructed by the Cartographic Division Soil Conservation Service USDA from USGS maps 1:250,000 Series Transverse Mercator Projection. Town lines and names from Massachusetts Department of Community Affairs map OCTOBER 1970

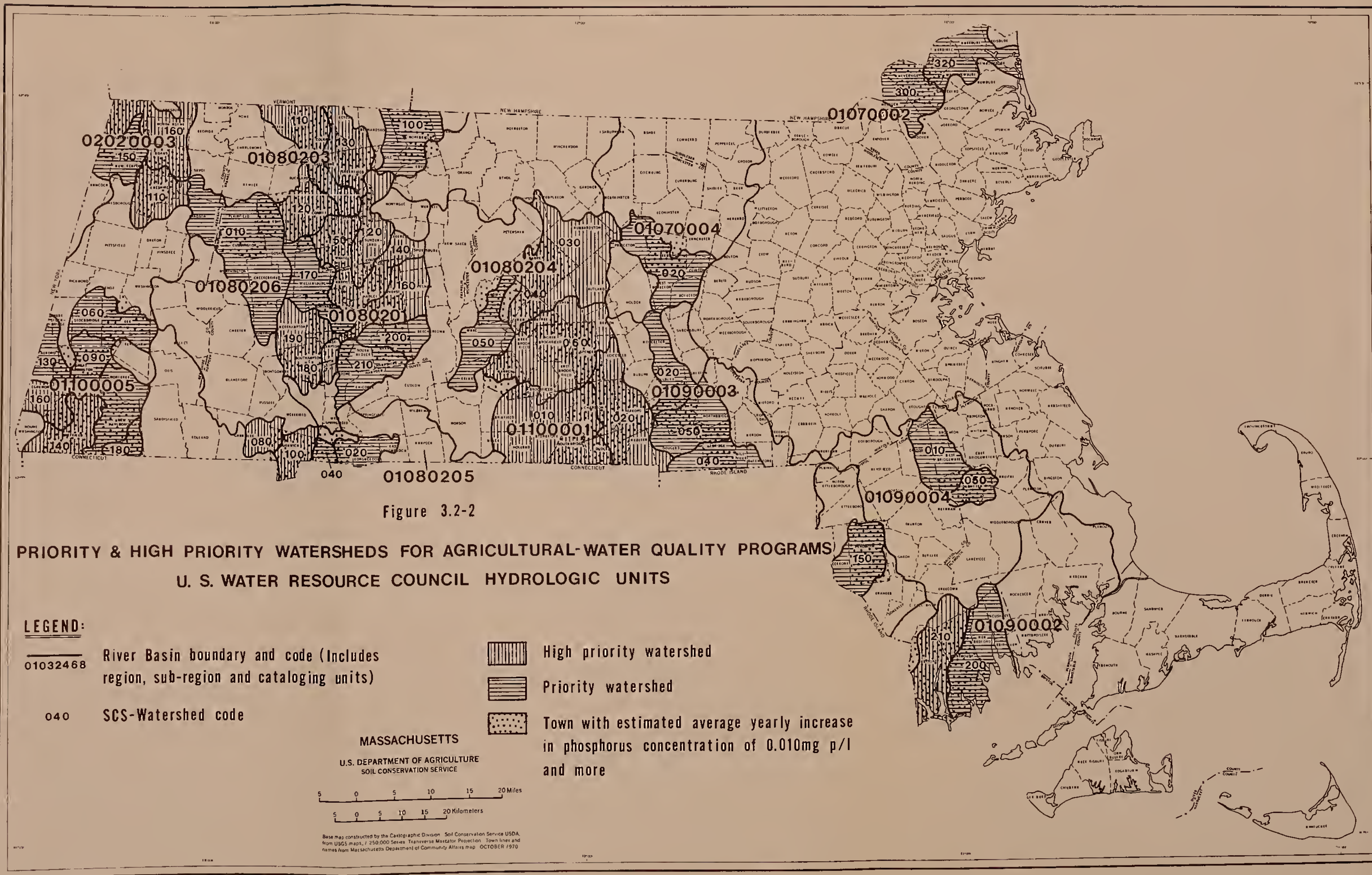


Figure 3.2-2

PRIORITY & HIGH PRIORITY WATERSHEDS FOR AGRICULTURAL-WATER QUALITY PROGRAMS
U. S. WATER RESOURCE COUNCIL HYDROLOGIC UNITS

TABLE 3.2-1 - High Priority and Priority Watersheds for Agriculture Water Quality Programs in Massachusetts (contd)

Basin and [1/] WS WRC 8-Digit Code Number	Watersheds SCS 3-Digit Code Number and Name	High Priority	Priority	Watershed Includes These High Priority Towns	Plus These Priority Towns
Southern Connecticut River Valley 01080205	020 Long Meadow Bk.		X		Agawam
	040 Stony R.		X	Southwick	Agawam
Chicopee River 01080204	030 Ware R.	X		New Braintree	Barre, Hardwick
	060 Upper Quaboag R.	X		New Braintree No. Brookfield	Spencer, Warren
	040 Danforth Bk.		X		Hardwick
	050 Ware R.		X	New Braintree	Hardwick, Barre, Warren
Quinebaug and French Rivers 01100001	010 Quinebaug R.	X		Dudley, Southbridge	Warren, Charlton
	020 French R.	X		Dudley	Charlton, Spencer, Oxford, Sutton
Blackstone River 01090003	020 Blackstone R.		X		Sutton
	040 Blackstone R.		X		Uxbridge
	050 Mumford R.		X		Sutton, Uxbridge
Nashua River 01070004	020 Stillwater R.		X		Sterling
Lower Merrimac River Valley 01070002	300 Merrimack R. Valley		X		Haverhill
	320 Merrimack R. Valley		X		Haverhill
South Coastal 01090002	210 Westport R.	X		Westport	Dartmouth
	200 Acushnet R.		X		Dartmouth
Taunton River 01090004	010 Town R.		X		Bridgewater
	050 Taunton R.		X		Bridgewater
	150 Palmer R.		X		Rehoboth

1/ USDA, Soil Conservation Service, Hydrologic Units, Massachusetts, Map and Area Measurements of U.S. Water Resources Council Hydrologic Units and Soil Conservation.

The watersheds with significant acreage of bogs which should be investigated further are:

Basin	Watershed	U.S. Water Resource Council & SCS 3-Digit Code 1/	Area-Acres
Southern Coastal	Agawam River	01090002-160	48,689
	Weweantic River	01090002-170	28,722
	Crane Brook	01090002-180	9,576
Taunton River	Winnetuxet River	01090004-040	22,527

See Figure 3.2-4, Cranberry Watersheds Recommended for Further Water Quality Monitoring, for the location of these watersheds.

3.3 FUTURE OF AGRICULTURE IN MASSACHUSETTS

The trend in agriculture in Massachusetts has been a long-term decline particularly since the 1940s. Recent information (the 1978 Federal Census of Agriculture) shows, however, that this long-term decline may be stopping. Agricultural statistics including acreage, number of farms, value of crop sold, etc., have shown a reversal of this declining trend for certain of the agricultural sectors. Dairy and poultry in 1978, however, still continue to show declines. At this time the agricultural community hopes that the stabilizing or increasing indications of the 1978 Census hold for the future and that these encouraging figures do not turn out to be just a minor adjustment in a further declining situation. 2/

The Commonwealth of Massachusetts has taken positive steps to reverse the declining trend in agriculture. One of the most important being the Agricultural Preservation Restriction Program which is actively purchasing development rights of agricultural land.

For this study, a set of projections were developed based on historical trends.

1/ USDA, Soil Conservation Service, Hydrologic Units Massachusetts, Map and Area Measurements of U.S. Water Resource Council Hydrologic Units and Soil Conservation Service Watershed Codes, July 1981.

2/ Bailey, Mark R., Lisa J. Rosenberger and Michael R. Kolman, with Mary Lee Rhodes and Vivian M. Brady, Massachusetts Agricultural Viability Study, USDA, ERS, SCS, and FS in cooperation with the Massachusetts Department of Food and Agriculture and the Massachusetts Agricultural Experiment Station, December 1982.

Projections for selected livestock and corn silage acreage were made using a semi-log projection technique. The projections were based on approximately 30 years of data from the Massachusetts Agricultural Statistics. Results of these projections for 1990, 1995, and 2000 are shown in the following table:

TABLE 3.3-1 - Projection of Historical Trends in Selected Sectors of Mass. Agriculture

Item	Units	YEAR 1980	1990	1995	2000
Corn silage	(acres)	40,000	43,000	46,000	48,000
Cattle	Hd.	104,000	74,000	66,000	58,000
Chickens	Hd.	1,790,000	1,208,000	1,000,000	828,000
Turkeys	Hd.	126,000	56,000	40,000	29,000
Hogs	Hd.	60,000	39,000	32,000	27,000
Sheep	Hd.	7,100	5,900	5,300	4,800

These projections are based on the assumption that the trends of the past 3 decades will continue. There has been recent evidence, the 1978 Census of Agriculture for example, that the fairly rapid declines in the agricultural activities occurring during the post World War II era have either been reversed or stabilized. Moreover, the state of Massachusetts has taken steps to revitalize the agricultural sector through such measures as agricultural land preservation, marketing assistance, and promotional techniques. In view of these developments the above projections may, for the most part, be somewhat pessimistic. All livestock categories show declines while the corn silage acreage indicates a rise. This is an apparent inconsistency since corn silage is produced primarily as feed for dairy cattle. However, these corn silage figures reflect a major change in dairy cattle feeding, a conversion from hay to corn silage by dairy farmers.

This set of projections is included to give the reader an idea of what little agriculture would remain in the state by the year 2000 if historical trends continue. There is, however, the strong possibility that an inflection point has been reached in Massachusetts agriculture. We may be at the beginning of a period of stability in agriculture and there is even the possibility that some sectors may gain in size in the future. For this reason it is suggested that the 1980 figures in Table 3.3-1 be used in place of the projected figures. This, therefore, projects no gross change in Massachusetts agriculture to the year 2000.

3.4 RECOMMENDATIONS

Recommendations of the study are:

1. The Massachusetts Department of Environmental Quality Engineering approve the set of Best Management Practices included here as Appendix B, as appropriate for statewide use for the reduction of nonpoint water quality problems originating from agricultural sources.

2. Determine the impaired use of water as a result of the phosphorus from agriculture. Further prioritize the 20 high priority watersheds based on this impaired use of water.

3. Implement the programs designed for agricultural water quality problems in the 20 high priority watersheds based on the information on impaired use developed under recommendation 2 above.

   These programs, described elsewhere, include the Watershed Protection and Flood Protection Act (PL 83-566), Rural Clean Water Program, Conservation Operations, Agricultural Conservation Program, and other USDA programs and clean lakes programs such as EPA's Section 314 Clean Lakes Program, and Massachusetts Clean Lakes and Great Ponds Program. Many of the above programs work best when applied concurrently in a problem area.

4. There is less urgency for the 25 watersheds designated as priority watersheds. Within these watersheds presently ongoing programs such as the Conservation Operations Program and the Agricultural Conservation Program should be emphasized.

   When the backlog for the high priority watersheds under the other more heavily funded programs mentioned in recommendation 3 is reduced, applications under these programs should be submitted for the priority watersheds.

5. Establish a monitoring program in one or more of the four watersheds; Agawam River, Weweantic River, Crane Brook, and Winnetuxet River, located in Massachusetts cranberry country, to develop additonal information on the downstream effects of fertilizer application on bogs.

6. Develop information for the pesticide contamination of groundwater problem which has recently surfaced in Massachusetts. Information is needed on:

   a. Pesticides - Which pesticides used, where and how much applied, and what degradation has occurred?

   b. Aquifers involved - Groundwater geologic information; volume, recharge and other characteristics is needed.

   c. Pesticides in aquifers - Such questions such as amount of pesticide in specific aquifers, concentrations and pesticide movement including transport to these aquifers need to be addressed.

   d. Clean up and removal methods - Appropriate methods, including costs, need to be determined.

   e. Pilot programs - Detailed investigations of specific contaminated aquifers are needed.

Chapter 4. IMPLEMENTATION

4.1 INITIATED PROJECTS

The Westport River in Bristol County is rated as a high priority watershed in this study. This is not new information to the citizens of the watershed as the Westport River has been selected to be the first Rural Clean Water Program project in the state. Nationwide, only the most severe examples of agricultural related pollution were selected for the Rural Clean Water Program.

The application for this program was prepared by the Bristol County office of the Agricultural Stabilization and Conservation Service working in conjunction with a local coordinating committee with membership representing federal, state, regional, conservation district, and town interests. U.S. Secretary of Agriculture Block approved this project for the program on June 5, 1981. Pollution of shellfish beds from agricultural runoff is the reason for the urgency in the Westport area. Undoubtedly, other pollution sources also contribute to this shellfish pollution problem.

The plan developed for this project called for the installation of: 15 Animal Waste Control Systems; BMPs such as conservation tillage, stripcropping systems, and permanent vegetative cover on 1715 acres of agricultural land; 5000 feet of streambank protection; fertilizer management on 1100 acres; and pesticide management on 2000 acres. 1/

The estimated installed costs of these BMP's is $804,000 of which federal cost-share funds will contribute $603,000 or 75 percent of the total. The remaining 25 percent of these costs will be borne by the landowner.

A conservation plan for water quality will be developed for each farm as needed that will detail which BMPs will be installed. Conservation plans for water quality place emphasis on water quality and may or may not address other aspects of conservation planning. A typical conservation plan is developed according to the landusers' objectives and may affect water quality off the farm. Conservation plans for water quality called for in this project will contain practices and systems which benefit water quality purposes. Cost-sharing will be provided only for practices and systems that benefit water quality.

After a slow start, progress is presently being made towards project goals. To date major components of Animal Waste Control Systems have been installed or are under construction for four of the original proposed 15 systems. These components include a paved feed lot, two roofed feed lots, and a manure storage structure. Erosion control BMPs such as stone-lined waterways and terraces have been installed under this program. In addition, other conservation measures are being installed in the watershed under the Agricultural Conservation Program (ACP).

1/ Local Coordinating Committee, Westport River RCWP Project, Rural Clean Water Program, Westport River Watershed Project Westport, Massachusetts, Plan of Work-1981.

4.2 HIGH PRIORITY WATERSHEDS

With the Westport River project underway, 19 high priority watersheds remain.

The planning process is underway for the agricultural water quality problems of the Upper Quaboag River Watershed in the Chicopee River Reporting Area under the Watershed Protection and Flood Prevention Act (Public Law 83-566). It is important that both the on-farm and off-farm water quality problems be defined in developing candidate PL-566 applications and continuing planning. The process that a typical proposed project will undergo is as follows:

1. Project sponsors prepare a brief preapplication report and complete a Preapplication for Federal Assistance form and submit these to the state clearinghouse for the Circular A-95 review.

2. Project sponsors prepare an application and submit to the Massachusetts Division of Water Resources for approval. Once state approval has been granted, the application is submitted to the SCS's State Conservationist for transfer to the SCS National Headquarters.

3. Once planning assistance is approved by the SCS, National Headquarters, the following steps are taken:

    a. Prepare a Plan of Work to guide and manage this planning process.

    b. Begin data collection, public participation program, and other planning efforts.

    c. Prepare a pre-authorization report. At this time the sponsors and agencies assisting them will know whether it is worth going ahead with the project. That is, that there is sufficient support from the farming community and the general public and that the project will be economically and environmentally justified.

4. SCS National Headquarters approves project for final planning.

    a. Complete planning process.

    b. Prepare a Plan and Environmental Impact Statement.

    c. Initiate review and approval process.

5. Project is approved for installation including authorization of needed funds.

Details of the application process may differ for other programs discussed earlier but the general format is similar for projects requiring large amounts of federal or state cost-sharing funds.

Along with beginning the application process in the other high priority watersheds emphasis could be given in the Conservation Operations and Agricultural Conservation programs in these watersheds. Updating of existing conservation plans and developing of additional conservation plans is the first step in the process of correcting water quality problems originating from agriculture.

4.3 ESTIMATED COSTS FOR BEST MANAGEMENT PRACTICES

The 16 Best Management Practices (BMP's) presented in Appendix B contain 57 individual conservation practices. Table 4.3-1 lists these practices and presents average installation costs for some of the more important practices. To determine the costs of installing the needed BMP's in one of the high priority watersheds, a more detailed analysis is required than is presently available. However, general costs can be estimated.

Table 4.3-1 - Listing of Conservation Practices from BMPs Selected for Massachusetts.

Practice Number	Conservation Practice	Units	Component of BMP Numbers	Average Installation Costs - Dollars 1/
312	Waste Management System	No.	2	15,000
313	Waste Storage Structure	No.	2	10,000
322	Channel Vegetation	Acre	10	800
328	Conservation Cropping System	Acre	8, 9	150
329	Conservation Tillage System	Acre	9	175
330	Contour Farming	Acre	9	10
340	Cover and Green Manure Crop	Acre	8, 14	30
342	Critical Area Planting	Acre	2, 11, 14	2,000
350	Sediment Basin	No.	12	2,000
356	Dike	Feet	2, 5, 12	10
359	Waste Treatment Lagoon	No.	2	8,000
362	Diversion	Feet	2, 5	2.50
378	Pond	No.	6	3,500
382	Fencing	Feet	1, 2, 6, 7, 10, 11, 12, 14	1.75
384	Fertilizer Management	Acre	15	5
386	Field Borders	Feet	11	0.60
392	Field Windbreaks	Feet	8	0.60
393	Filter Strip	Acre	10, 11	1,700
410	Grade Stabilization Structure	No.	12	800
412	Grassed Waterway or Outlet	Acre	2, 7	1,700
425	Waste Storage Pond	No.	2	7,000
428	Irrigation Water Conveyance, Ditch and Canal	Feet	13	2
430	Irrigation Water Conveyance, Pipeline	Feet	13	2.50
441	Irrigation System, Drip	No. & Acre	13	1,900
442	Irrigation System, Sprinkler	No. & Acre	2, 13	2,000
447	Irrigation System, Tailwater Recovery	No.	13	5,000
449	Irrigation Water Management	Acre	13	25
468	Lined Waterway or Outlet	Feet	7	7

1/ When both Number and Acres are listed under Units, Cost given is per Acre.

Table 4.3-1 - Listing of Conservation Practices from BMPs Selected for Massachusetts. (contd)

Practice Number	Conservation Practice	Units	Component of BMP Numbers	Average Installation Costs - Dollars 1/
472	Livestock Exclusion	Acre	11	300
484	Mulching	Acre	11	300
490	Woodland Site Preparation	Acre	14	200
500	Obstruction Removal	Acre	3, 4, 5	500
510	Pasture & Hayland Management	Acre	1	75
512	Pasture & Hayland Planting	Acre	1	250
514	Pesticide Management	Acre	16	5
516	Pipeline	Feet	6	3
521	Pond Sealing or Lining	No.	6	3,000
558	Roof Runoff Management	No.	2	2/
559	Roofing for Runoff Control (limited use)	No.	2	2/
572	Spoilbank Spreading	Feet	11	2
574	Spring Development	No.	6	500
580	Streambank Protection	Feet	10	25
585	Stripcropping, Contour	Acre	3	70
586	Stripcropping, Field	Acre	3	60
587	Structure for Water Control	No.	12, 13	600
589	Stripcropping, Wind	Acre	3	40
600	Terraces	Feet	4	8
606	Subsurface Drain	Feet	2, 4, 5, 7, 13	3
607	Surface Drainage, Field Ditch	Feet	2, 13	2
608	Surface Drainage, Main or Lateral	Feet	2, 13	2.50
612	Tree Planting	Acre	10, 11, 14	350
614	Trough or Tank	No.	6	400
620	Underground Outlet	Feet	4, 5, 13	4.50
633	Waste Utilization	No. & Acre	2	40
638	Water & Sediment Control Basin	No.	12	3,000
642	Well	No.	6	600
652	Woodland Direct Seeding	Acre	14	9

1/ When both Number and Acres are listed under Units, Cost given is per Acre.
2/ No cost data available yet.

A preliminary cost figure for BMPs needed in the Upper Quaboag River Watershed in the Chicopee River Reporting Area is $600,000 based upon:

A.	Waste management systems for 20 dairy herds	$500,000
B.	Cropland protection systems, including streambank protection and critical area treatment for 2000 acres of cropland	100,000

It is estimated that the installation costs of the needed BMPs will vary from $0.5 million to $2 million per watershed in the high priority watersheds.

APPENDIX A: REGIONAL PROBLEM AREA SUMMARY

APPENDIX A: REGIONAL PROBLEM AREA SUMMARY

Table of Contents

Chapter A1. INTRODUCTION

Appendix A is essentially a technical appendix in which the major analyses performed in this study are presented.

In Chapters A2 and A3 the lesser agricultural areas of the state are eliminated in order to concentrate on the greater agricultural areas.

Chapters A4 through A9 present results of the technical analysis of soil erosion and animal waste and their possible effects on water quality. Chapters A5 through A9, which cover five different regions, are similar in language and format. It is anticipated that a reader would not read all five chapters but instead would select one or two of special interest.

Chapter A10 briefly discusses the status of conservation planning.

Chapters A11 and A12 discuss fertilizer and pesticide use in agriculture.

Chapter A13 is a reprint of Working Paper #3, Erosion Estimates on Agricultural Land, which was distributed earlier in this study.

Chapter A2. SELECTION OF STUDY AREA

One of the initial tasks of this study was to eliminate those areas of Massachusetts with little or no agriculture. The remaining area would be, therefore, the initial study area for this project. This task consisted of a two-step selection process:

1. Develop criteria for selection.

2. Use criteria to select area for study.

Criteria for Selection

All of Massachusetts is incorporated into 351 cities and towns. These local units of government were selected for subdivision of the study area because of their powers of regulation and enforcement.

The criteria for inclusion in the area of study are:

1. Cities and towns with 1,000 or more acres of agricultural land.

   The data source for this land use information is the 1971-1972 Land Use data developed by W.P. MacConnell and Associates at the University of Massachusetts, Amherst. Agricultural land use types include the following as defined by MacConnell et al.:

   T - Tilled cropland
   TU - Unused tillable land
   P - Pasture or wild hay land
   O - Productive fruit orchard
   CB - Productive cranberry bog
   N - Nurseries, tree and shrub nurseries, including greenhouses

2. Cities and towns with less than 1,000 acres of agricultural land as defined in 1 above, but with four or more dairy herds listed for the community in the Massachusetts Department of Food and Agriculture 1979 Listing.

Selection

This criteria selects 177 cities and towns for the Study Area, as shown on Figure A2-1. Table A2-1, Agricultural Land in Selected Towns and Cities, summarizes the total agricultural land by county and the amount in the selected municipalities. About 85 percent of the total agricultural land in Massachusetts is in the 177 selected cities and towns. Table A2-2, Cities and Towns Which Do Not Meet Selection Criteria, lists the agricultural land use and numbers of dairy herds for 174 municipalities excluded from further study.

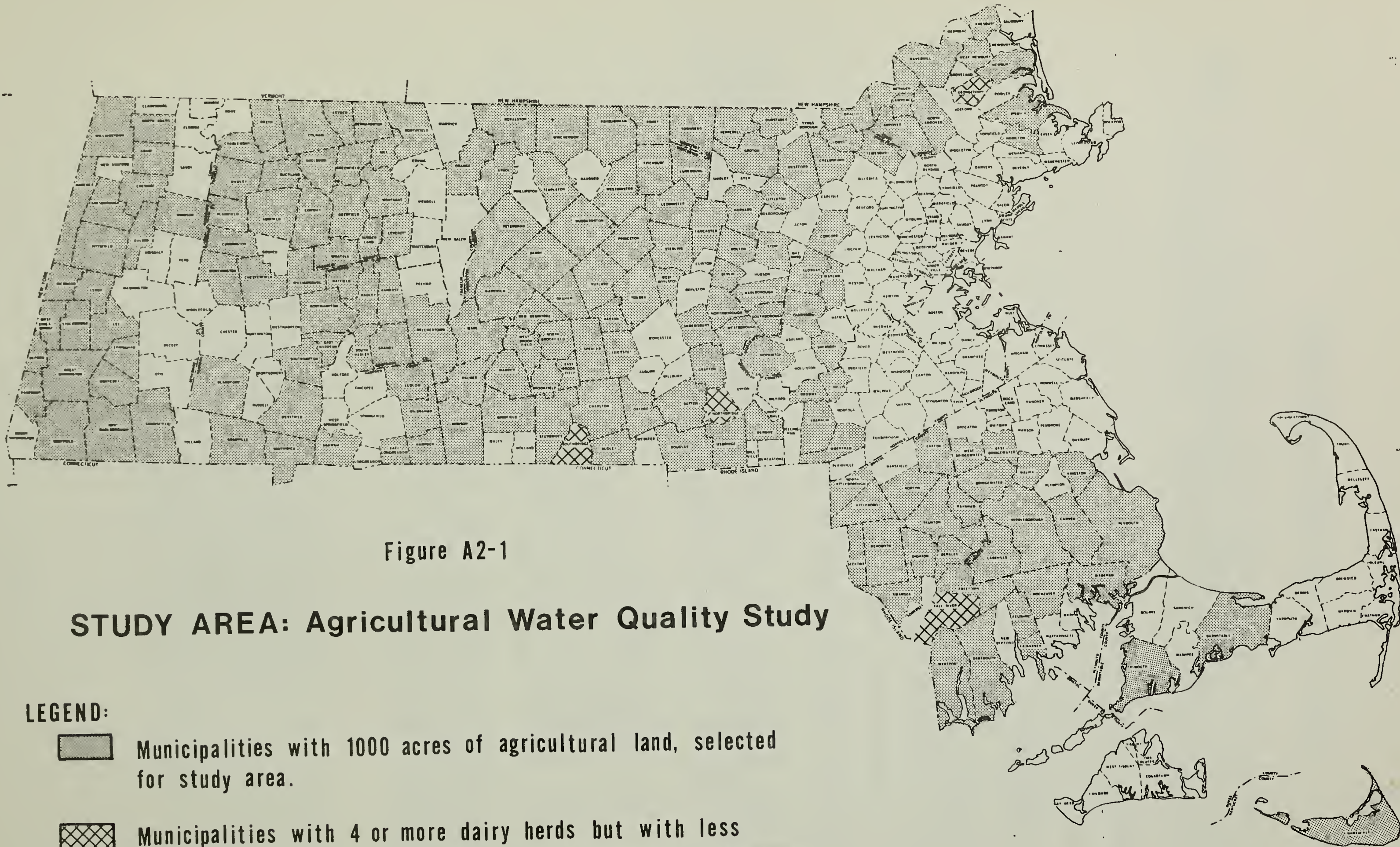


Figure A2-1

STUDY AREA: Agricultural Water Quality Study

LEGEND:

- (shaded) Municipalities with 1000 acres of agricultural land, selected for study area.
- (cross-hatched) Municipalities with 4 or more dairy herds but with less than 1000 acres of agricultural land, selected for study area.

Land Use Data Source: 1971-72 Land Use developed by W. P. MacConnell et al. at UMass, Amherst, Ma.

TABLE A2-1 - Agricultural Land in Selected Towns and Cities

County	Total Agricultural Land - Ac.	Number of Selected Towns/Cities	Agri. Land in Selected Towns/ Cities - Ac 1/	Percent of Selected Towns/ Cities Agri. Land of Total Agri. Land
Suffolk	159	0	0	0
Norfolk	12,345	4	5,018	40.6
Barnstable	6,739	2	2,902	43.1
Dukes	2,753	0	0	0
Nantucket	1,187	1	1,187	100.
Plymouth	36,665	11	29,565	80.6
Bristol	38,970	17	37,204	95.5
Middlesex	39,358	18	28,499	72.4
Essex	26,834	10	16,952	63.2
Worcester	95,210	46	88,162	92.6
Franklin	52,896	19	49,627	93.8
Hampshire	49,644	15	46,293	93.2
Hampden	33,070	12	28,103	85.0
Berkshire	65,915	22	60,772	92.2
Totals	461,745	177	394,284	85.4

1/ MacConnell, William P., Remote Sensing 20 Years of Change in Franklin County, Massachusetts 1952-1972, and ten other similar publications by MacConnell et al., which includes all of Massachusetts, Massachusetts Agricultural Experiment Station, Univ. of Mass., at Amherst, Mass., 1975.

TABLE A2-2 - Cities and Towns Which Do Not Meet Selection Criteria

County	City/Town	1971-1972 Agric. Land Use 1/ Ac.	No. of Dairy Herds 2/
Barnstable	Bourne	384	
	Brewster	403	
	Chatham	127	
	Dennis	231	
	Eastham	152	
	Harwich	502	
	Mashpee	370	
	Orleans	223	
	Provincetown	8	
	Sandwich	884	
	Truro	84	
	Wellfleet	77	
	Yarmouth	392	
Dukes	Chilmark	393	
	Edgartown	991	
	Gay Head	0	
	Gosnold	230	
	Oak Bluffs	230	
	Tisbury	119	
	West Tisbury	790	1
Bristol	Mansfield	838	1
	New Bedford	199	1
	Somerset	722	3

1/ MacConnell, William P., Remote Sensing 20 Years of Change in Franklin County, Massachusetts 1952-1972, Massachusetts Agricultural Experiment Station, Univ. of Mass., at Amherst, Mass., 1975, and ten other similar publications by MacConnell et al.

2/ Dairy herd listing provided by Massachusetts Dept. of Food and Agriculture, July 1979.

TABLE A2-2 - Cities and Towns Which Do Not Meet Selection Criteria (contd)

County	City/Town	1971-1972 Agric. Land Use 1/ Ac.	No. of Dairy Herds 2/
Plymouth	Abington	338	1
	Brockton	314	
	Duxbury	827	1
	Hanover	343	
	Hanson	797	
	Hingham	471	
	Hull	19	
	Marion	347	
	Marshfield	615	
	Mattapoisett	590	
	Norwell	357	1
	Pembroke	670	
	Plympton	885	
	Rockland	58	
	Scituate	244	
	Whitman	225	2
Norfolk	Avon	11	
	Bellingham	837	1
	Braintree	59	
	Brookline	51	
	Canton	671	2
	Cohasset	47	
	Dedham	45	
	Dover	576	
	Foxborough	430	2
	Holbrook	89	1
	Medfield	623	
	Milton	196	
	Needham	173	
	Norfolk	833	3
	Norwood	117	
	Plainfield	500	
	Quincy	0	
	Randolph	66	
	Sharon	506	1
	Stoughton	404	
	Walpole	708	2
	Wellesley	61	
	Westwood	226	
	Weymouth	98	
Suffolk	Boston	144	
	Chelsea	0	
	Revere	15	
	Winthrop	0	

TABLE A2-2 - Cities and Towns Which Do Not Meet Selection Criteria (contd)

County	City/Town	1971-1972 Agric. Land Use 1/ Ac.	No. of Dairy Herds 2/
Middlesex	Acton	850	
	Arlington	8	
	Ashland	426	
	Ayer	241	
	Bedford	461	
	Belmont	39	
	Billerica	694	
	Boxborough	671	
	Burlington	175	
	Cambridge	10	
	Carlisle	791	
	Everett	0	
	Holliston	687	
	Hudson	602	
	Lexington	477	
	Lincoln	968	
	Lowell	115	
	Malden	0	
	Maynard	55	
	Medford	0	
	Melrose	0	
	Natick	556	
	Newton	64	
	North Reading	176	
	Reading	62	
	Shirley	867	
	Somerville	0	
	Stoneham	74	
	Tyngsborough	679	3
	Wakefield	45	
	Waltham	274	
	Watertown	39	
	Weston	278	
	Wilmington	78	
	Winchester	34	
	Woburn	359	
Essex	Beverly	473	
	Boxford	975	
	Danvers	914	1
	Essex	647	
	Gloucester	45	
	Groveland	398	
	Lawrence	50	
	Lynn	0	
	Lynnfield	104	

TABLE A2-2 - Cities and Towns Which Do Not Meet Selection Criteria (contd)

County	City/Town	1971-1972 Agric. Land Use 1/ Ac.	No. of Dairy Herds 2/
Essex (cont.)	Manchester	4	
	Marblehead	19	
	Merrimac	798	1
	Middleton	721	1
	Nahant	0	
	Newburyport	801	1
	Peabody	433	1
	Rockport	129	
	Rowley	968	2
	Salem	46	
	Salisbury	778	1
	Saugus	70	
	Swampscott	15	
	Topsfield	898	
	Wenham	598	
Worcester	Auburn	952	2
	Blackstone	907	1
	Boylston	457	
	Clinton	102	
	East Brookfield	678	2
	Gardner	707	
	Hopedale	29	
	Milford	153	
	Millbury	906	2
	Millville	127	
	Phillipston	610	
	Upton	796	2
	Webster	259	
	Worcester	365	
Franklin	Erving	299	
	Monroe	100	
	New Salem	691	
	Rowe	492	1
	Shutesbury	215	
	Warwick	967	
	Wendell	505	
Hampshire	Goshen	352	1
	Huntington	792	2
	Middlefield	935	3
	Pelham	303	
	Westhampton	969	2

TABLE A2-2 - Cities and Towns Which Do Not Meet Selection Criteria (contd)

County	City/Town	1971-1972 Agric. Land Use 1/ Ac.	No. of Dairy Herds 2/
Hampden	Chester	717	
	Chicopee	605	
	Holland	187	
	Holyoke	756	1
	Longmeadow	332	
	Montgomery	438	
	Russell	106	
	Springfield	309	
	Tolland	246	
	Wales	335	
	West Springfield	936	1
Berkshire	Becket	389	
	Clarksburg	486	
	Florida	638	
	Hinsdale	946	1
	Mt. Washington	374	
	New Ashford	537	1
	Otis	394	1
	Peru	139	2
	Savoy	843	
	Washington	397	

Discussion

The cities and towns excluded from further study are either heavily urbanized, or forested, or coastal communities with poor agricultural soils. The Boston metropolitan area is an example of a highly urbanized area which contains little or no agriculture. Heavily forested towns, particularly in western Massachusetts, are characterized by low populations, and hilly or rugged topography. These "hill" towns once supported substantial amounts of agriculture but many of the farms were on steep terrain better suited to forest and have since reverted to forest cover. Examples of coastal towns with poor agricultural soils are Cape Cod towns such as Eastham or Chatham. These towns are now oriented towards summer recreation and tourism but they never did have any substantial amount of agriculture.

Chapter A3. SELECTION OF CONCENTRATED AGRICULTURAL AREAS

The next step in the study was to obtain recent agricultural land use data and livestock and poultry numbers for the 177 cities and towns selected for further study.

Location of Agricultural Lands

The agricultural land use was developed in two principal ways. Recent land use mapping from the Massachusetts Natural Resources Planning Program or other sources such as the Current Land Use Map in the 201/EIS Report - Nantucket Wastewater Treatment Facilities, prepared by Anderson-Nichols & Co., Inc., were used to determine agricultural land use for about six towns. For the remainder of the 177 municipalities, SCS personnel went to these municipalities and field checked the agricultural land use shown on the 1971-72 Massachusetts Map Down (MMD) quadrangle sheets produced by W. P. MacConnell and associates at the University of Massachusetts, Amherst. Over 80 percent of the agricultural lands were visually inspected in this procedure.

Mapping of productive cranberry bogs was supplied from The Pilgrim Resource Conservation and Development Project.

During the field inspections, changes from agricultural land to urban land, abandoned fields and other open non-agricultural land uses were noted. In addition, changes from non-agricultural land uses to agricultural uses were mapped. Usually this consisted of re-establishing agricultural use in recently abandoned fields.

The total agricultural land in Massachusetts from the 1971-72 MMD project is 461,749 acres. Table A3-1, Change in Agricultural Land Acreage in Selected Towns and Cities from 1971-72 to 1980, lists the 1971-72 agricultural land acreage for the 177 municipalities as 394,384 acres or 85.4 percent of the state total. The 177 municipalities have lost approximately 107,000 acres of agricultural land from 1971-72 to 1980. This loss reflects the net change from the 1971-72 MMD land use map data and area statistics to 1980.

The 1971-72 MMD agricultural land use type, tilled land, included row crops, hayland, and other cropland. As there is a major difference in the potential erosion from these varying vegetative covers, study needs required that we know whether a field is in row crops, hay or possibly in a crop rotation.

Table A3-3 lists the 1980 agricultural land use data for 177 cities and towns in the study area.

TABLE A3-1 - Change in Agricultural Land Acreage in Selected Towns and Cities from 1971-1972 to 1980.

County	Number of Towns/Cities Selected	1971-72 Area of Ag Land in Selected Towns/Cities Ac 1/	1980 Area of Ag Land in Selected Towns/Cities Ac	Change Acres	Change Percent
Barnstable	2	2,902	1,138	1,764	60.8
Berkshire	22	60,772	46,179	14,593	24.0
Bristol	17	37,204	23,936	13,268	35.7
Dukes	0	-	-	-	-
Essex	10	16,952	11,387	5,565	32.8
Franklin	19	49,627	40,784	8,843	17.8
Hampden	12	28,103	21,595	6,508	23.2
Hampshire	15	46,393	37,406	8,987	19.4
Middlesex	18	28,499	18,907	9,592	33.7
Nantucket	1	1,187	833	354	29.8
Norfolk	4	5,018	3,247	1,771	35.3
Plymouth	11	29,565	20,307	9,258	31.3
Suffolk	0	-	-	-	-
Worcester	46	88,162	61,186	26,976	30.6
Totals	177	394,384	286,905	107,479	27.3

1/ MacConnell, William P., Remote Sensing 20 Years of Change in Franklin County, Massachusetts 1952-1972, and ten other similar publications by MacConnell et al., which includes all of Massachusetts, Massachusetts Agricultural Experiment Station, Univ. of Mass., at Amherst, Mass., 1975.

Livestock and Poultry Numbers

The livestock numbers were originally obtained from the Massachusetts Department of Food and Agriculture. Corrections, based on field information obtained by SCS personnel were made when possible. Poultry information was obtained by SCS with the assistance of the Massachusetts Extension Service and the Massachusetts Department of Food and Agriculture. Turkey farms with less than 1,000 birds, and chicken and duck operations with less than 2,500 birds were excluded from the inventory. Only one duck farm was inventoried in Massachusetts.

The livestock and poultry numbers were converted to animal units. An animal unit is a convenient measuring unit for figuring feeding quantities and manure production. A 1,000 pound dairy cow would equal one animal unit. Table A3-2, Animal Units, lists the animal unit values used in this study. Table A3-3 lists the livestock and poultry in animal units for 177 cities and towns in the study area.

TABLE A3-2 - Animal Units 1/

Animal	Weight Range lbs.	Average Weight	Animal Units per Animal	Number of Animals per AU
Dairy Cattle				
Cows (2 yrs. & older)	800-1400	1400	1.4	0.7
Heifers (1 to 2 yrs.)	500-1200	700	0.7	1.4
Calves	75-700	400	0.4	2.5
Bulls	900-1500	1400	1.4	0.7
Beef Cattle 1 yr. ave. wt. 600 lbs. 2 yrs. ave. wt. 1100 lbs.		1000	1.0	1.0
Oxen	1200+	1400	1.4	0.7
Horses (2 yrs. & older)	400-1300	1000	1.0	1.0
Ponies, Donkeys	400-800	600	0.6	1.7
Sheep	100-180	140	0.14	7.
Goats	50-150	125	0.125	8.
Pigs	40-400+	280	0.28	3.5
Ducks	4-7	5	0.005	200
Chickens	4-5	4	0.004	250
Turkeys	5-25	10	0.01	100

1/ Values from SCS Agricultural Waste Management Manual, Loading Functions for Assessment of Water Pollution from Nonpoint Sources EPA (600/2-76-151) and from field experience of SCS personnel in Massachusetts.

MASSACHUSETTS AGRICULTURAL WATER QUALITY STUDY

TABLE A3-3 - AGRICULTURAL LAND USE AND LIVESTOCK AND POULTRY STATISTICS

Basin No. and Name	City/Town	1980 Agricultural Land Use: Cropland Ac.	Hay & Pasture Ac.	Orchards Nurseries Ac.	Cran-berry Ac.	Total Ac.	Livestock 1/: Dairy Number	Dairy AU 2/	Beef AU	Other 3/ AU	Total Total AU	Poultry Detailed AU	Livestock & Poultry AU	Selected for Analysis
1. Hoosic	Adams	556	1,466	50	-	2,072	881	995	85	29	1,109	-	1,109	*
	Cheshire	653	3,139	-	-	3,792	1,200	1,350	38	79	1,467	-	1,467	*
	Hancock	212	1,474	-	-	1,686	427	452	80	41	573	-	573	
	North Adams	72	163	-	-	235	51	63	107	65	235	-	235	
	Williamstown	1,223	3,379	64	-	4,666	1,385	1,553	252	177	1,982	66	2,048	*
	Subtotal	(2,716)	(9,621)	(114)	-	(12,451)	(3,944)	(4,413)	(562)	(391)	(5,366)	(66)	(5,432)	
2. Housatonic	Alford	329	1,208	-	-	1,537	689	768	12	11	791	-	791	
	Dalton	5	548	21	-	574	82	82	89	91	262	-	262	
	Egremont	930	1,400	36	-	2,366	534	562	70	45	677	-	677	
	Gt. Barrington	1,365	2,044	41	-	3,450	379	443	57	122	622	-	622	*
	Lanesborough	1,141	935	12	-	2,088	181	205	26	30	261	-	261	
	Lee	1,010	215	-	-	1,225	687	755	210	115	1,080	-	1,080	*
	Lenox	69	584	-	-	653	26	27	30	181	238	-	238	
	Monterey	259	418	-	-	677	93	95	52	38	185	-	185	
	New Marlborough	1,108	2,197	2	-	3,307	215	218	119	118	455	-	455	*
	Pittsfield	686	1,729	6	-	2,421	471	489	40	31	560	45	605	
	Richmond	315	1,881	29	-	2,225	232	254	69	28	351	40	391	
	Sheffield	3,719	3,295	61	-	7,075	2,772	2,961	210	135	3,306	-	3,306	*
	Stockbridge	114	1,252	-	-	1,366	19	17	56	47	120	-	120	
	Tyringham	250	892	-	-	1,142	557	584	48	34	666	-	666	
	W. Stockbridge	205	1,506	6	-	1,717	151	168	46	33	247	-	247	
	Subtotal	(11,505)	(20,104)	(214)		(31,823)	(7,088)	(7,628)	(1,134)	(1,059)	(9,821)	(85)	(9,906)	
3. Deerfield	Ashfield	344	2,524	119	-	2,987	1,559	1,702	91	56	1,849	-	1,849	*
	Buckland	146	782	140	-	1,068	617	625	82	51	758	-	758	
	Charlemont	444	881	2	-	1,327	226	232	28	40	300	-	300	
	Colrain	994	2,303	152	-	3,449	895	882	258	55	1,195	-	1,195	*
	Conway	389	2,058	17	-	2,464	696	766	140	126	1,032	-	1,032	*
	Greenfield	1,069	1,034	7	-	2,110	643	727	232	138	1,097	-	1,097	*
	Hawley	206	705	2	-	913	332	242	44	11	297	-	297	
	Heath	247	899	30	-	1,176	417	458	50	29	537	-	537	
	Leyden	216	1,084	27	-	1,327	560	572	51	20	643	-	643	
	Shelburne	627	1,601	419	-	2,647	1,044	1,135	187	119	1,441	-	1,441	*
	Subtotal	(4,682)	(13,871)	(915)	-	(19,468)	(6,989)	(7,341)	(1,163)	(645)	(9,149)	-	(9,149)	

1/ See Table A3-2 for the correspondence of various animals and poultry with Animal Units.
2/ AU Animal Units. For example, a 1000 lb. cow equals 1 animal unit.
3/ Other includes horses, ponies, donkeys, sheep, goats and swine.
4/ Poultry includes chickens, turkeys and ducks. There is only one duck operation of any size in Massachusetts. Only chicken and duck farms with over 2500 birds and turkey farms with over 1000 birds are included in these figures.

TABLE A3-3 - AGRICULTURAL LAND USE AND LIVESTOCK AND POULTRY STATISTICS

Basin No. and Name	City/Town	1980 Agricultural Land Use: Cropland Ac.	Hay & Pasture Ac.	Orchards Nurseries Ac.	Cran-berry Ac.	Total Ac.	Livestock 1/: Dairy Number	Dairy Au 2/	Beef AU	Other 3/ AU	Total AU	Poultry 4/ AU	Livestock & Poultry Total AU	Selected for Detailed Analysis
4. Westfield	Blandford	145	717	28	-	890	11	11	17	86	114	-	114	
	Chesterfield	17	853	109	-	979	232	232	35	29	296	-	296	
	Cummington	386	817	18	-	1,221	932	1,062	7	51	1,120	-	1,120	*
	Granville	124	528	387	-	1,039	516	539	78	44	661	-	661	
	Plainfield	383	628	6	-	1,017	95	103	17	33	153	-	153	
	Southwick	2,008	2,085	71	-	4,164	946	1,070	284	495	1,849	52	1,901	*
	Westfield	1,709	1,727	110	-	3,546	952	1,101	23	18	1,142	-	1,142	*
	Windsor	17	1,044	-	-	1,061	57	49	115	32	196	-	196	
	Worthington	402	998	-	-	1,400	61	60	88	51	199	-	199	
	Subtotal	(5,191)	(9,397)	(729)	-	(15,317)	(3,793)	(4,227)	(664)	(839)	(5,730)	(52)	(5,782)	
5. Farmington	Sandisfield	91	753	-	-	844	28	30	70	37	137	-	137	
	Subtotal	(91)	(753)	-	-	(844)	(28)	(30)	(70)	(37)	(137)	-	(137)	
6. Connecticut	Agawam	1,989	544	73	-	2,606	148	167	37	87	291	10	301	*
	Amherst	1,397	2,374	227	-	3,998	774	924	3	170	1,097	78	1,175	*
	Bernardston	895	1,041	-	-	1,936	638	693	39	77	809	-	809	
	Deerfield	3,469	1,594	69	-	5,132	1,979	2,159	133	113	2,405	-	2,405	*
	Easthampton	853	701	99	-	1,653	918	987	107	144	1,238	-	1,238	*
	E. Longmeadow	391	429	43	-	863	32	36	72	178	286	175	461	
	Gill	1,185	788	8	-	1,981	380	405	17	83	505	25	530	
	Granby	990	1,862	45	-	2,897	576	605	38	94	737	28	765	*
	Hadley	4,595	2,065	79	-	6,739	1,954	2,063	131	381	2,575	-	2,575	*
	Hampden	251	567	92	-	910	96	96	90	145	331	-	331	
	Hatfield	2,987	457	9	-	3,453	366	336	128	79	543	-	543	*
	Leverett	175	540	2	-	717	3	3	27	160	190	-	190	
	Montague	587	1,243	33	-	1,863	427	500	50	129	679	-	679	
	Northampton	2,298	847	25	-	3,170	395	455	22	65	542	-	542	*
	Northfield	2,223	1,210	-	-	3,433	1,908	1,969	38	88	2,095	-	2,095	*
	South Hadley	679	925	47	-	1,651	558	625	47	118	790	-	790	
	Southampton	895	1,601	18	-	2,514	986	1,025	56	161	1,242	-	1,242	*
	Sunderland	1,845	255	-	-	2,100	410	419	30	41	490	-	490	
	Whately	1,675	1,105	20	-	2,800	185	207	12	28	247	-	247	*
	Wilbraham	185	572	141	-	898	120	157	4	15	176	100	276	
	Williamsburg	254	739	42	-	1,035	652	726	51	100	877	-	877	
	Subtotal	(29,818)	(21,459)	(1,072)	-	(52,349)	(13,505)	(14,557)	(1,132)	(2,456)	(18,145)	(416)	(18,561)	

TABLE A3-3 - AGRICULTURAL LAND USE AND LIVESTOCK AND POULTRY STATISTICS

Basin No. and Name	City/Town	1980 Agricultural Land Use: Cropland Ac.	Hay & Pasture Ac.	Orchards Nurseries Ac.	Cran-berry Ac.	Total Ac.	Livestock 1/: Dairy Number	Dairy AU 2/	Beef AU	Other 3/ AU	Total AU	Poultry 4/ AU	Livestock & Poultry AU	Selected for Detailed Analysis
7. Millers	Athol	105	596	-	-	701	143	154	74	139	367	-	367	
	Orange	232	1,092	30	-	1,354	285	287	10	71	368	-	368	
	Royalston	59	625	2	-	686	151	162	6	32	200	-	200	
	Templeton	267	958	2	-	1,227	369	420	35	75	530	-	530	
	Winchendon	229	724	9	-	962	315	382	14	79	475	-	475	
	Subtotal	(892)	(3,995)	(43)	-	(4,930)	(1,263)	(1,405)	(139)	(396)	(1,940)	-	(1,940)	
8. Chicopee	Barre	1,040	1,673	-	-	2,713	784	857	148	196	1,201	-	1,201	*
	Belchertown	906	2,433	381	-	3,720	601	618	146	221	985	92	1,077	*
	Brookfield	136	606	58	-	800	366	372	27	112	511	-	511	
	Hardwick	921	2,113	5	-	3,039	1,830	1,985	85	44	2,114	-	2,114	*
	Hubbardston	218	932	28	-	1,178	219	221	198	135	554	180	734	
	Ludlow	193	1,099	2	-	1,294	260	292	73	82	447	-	447	
	Monson	627	1,295	117	-	2,039	673	714	123	150	987	-	987	*
	New Braintree	1,176	2,031	27	-	3,234	851	892	304	235	1,431	320	1,751	*
	N. Brookfield	812	1,630	159	-	2,601	855	950	65	79	1,094	628	1,722	*
	Oakham	220	578	18	-	816	277	297	80	42	419	-	419	
	Palmer	396	1,287	58	-	1,741	497	536	50	49	635	10	645	
	Paxton	401	332	-	-	733	417	470	6	44	520	-	520	
	Petersham	122	730	-	-	852	134	147	50	54	251	-	251	
	Rutland	496	877	11	-	1,384	340	382	96	63	541	-	541	
	Spencer	835	1,422	47	-	2,304	826	901	61	62	1,024	-	1,024	*
	Ware	420	1,530	9	-	1,959	620	728	33	55	816	-	816	
	Warren	511	1,428	99	-	2,038	820	879	25	56	960	140	1,100	*
	W. Brookfield	604	991	-	-	1,595	374	384	176	121	681	36	717	
	Subtotal	(10,034)	(22,987)	(1,019)	-	(34,040)	(10,744)	(11,625)	(1,746)	(1,800)	(15,171)	(1,406)	(16,577)	
9. French & Quinebaug	Brimfield	396	1,103	106	-	1,605	596	750	67	97	914	-	914	*
	Charlton	829	1,673	87	-	2,589	866	984	34	73	1,091	-	1,091	*
	Dudley	1,131	1,126	13	-	2,270	923	1,031	53	67	1,151	-	1,151	*
	Leicester	325	689	25	-	1,039	288	299	49	220	568	-	568	
	Oxford	519	595	110	-	1,224	269	279	91	740	1,110	-	1,110	*
	Southbridge	220	386	-	-	606	138	159	5	17	181	448	629	*
	Sturbridge	206	393	34	-	633	44	42	3	264	309	-	309	
	Subtotal	(3,626)	(5,965)	(375)	-	(9,966)	(3,124)	(3,544)	(302)	(1,478)	(5,324)	(448)	(5,772)	

TABLE A3-3 - AGRICULTURAL LAND USE AND LIVESTOCK AND POULTRY STATISTICS

Basin No. and Name	City/Town	1980 Agricultural Land Use: Cropland Ac.	Hay & Pasture Ac.	Orchards Nurseries Ac.	Cran-berry Ac.	Total Ac.	Livestock 1/: Dairy Number	Dairy AU 2/	Beef AU	Other 3/ AU	Total AU	Poultry 4/ AU	Livestock & Poultry AU	Selected for Detailed Analysis
10. Nashua	Ashburnham	121	389	48	-	558	34	26	19	95	140	50	190	
	Ashby	206	593	105	-	904	185	157	23	139	319	-	319	
	Fitchburg	143	386	238	-	767	372	495	0	26	521	166	687	
	Groton	396	1,251	401	-	2,048	6	8	349	41	398	-	398	
	Harvard	274	670	692	-	1,636	372	489	30	93	612	-	612	
	Holden	284	335	12	-	631	269	307	54	239	600	-	600	
	Lancaster	550	633	109	-	1,292	172	181	65	67	313	90	403	
	Leominster	126	331	243	-	700	114	118	10	14	142	-	142	
	Lunenburg	363	861	137	-	1,361	357	401	85	119	605	800	1,405	
	Pepperell	620	1,110	146	-	1,876	418	463	105	190	758	-	758	
	Princeton	450	810	-	-	1,260	162	168	51	280	499	-	499	
	Sterling	613	1,526	722	-	2,861	809	876	170	1,007	2,053	15	2,068	*
	Townsend	279	607	4	-	890	263	296	137	119	552	132	684	
	W. Boylston	20	503	-	-	523	82	92	63	131	286	-	286	
	Westminster	132	617	18	-	767	142	160	79	108	347	160	507	
	Subtotal	(4,577)	(10,622)	(2,875)	-	(18,074)	(3,757)	(4,237)	(1,240)	(2,668)	(8,145)	(1,413)	(9,558)	
11. Blackstone	Douglas	108	400	-	-	508	125	135	42	-	177	-	177	
	Grafton	1,177	859	96	-	2,132	544	560	44	149	753	-	753	
	Mendon	319	608	18	-	945	191	206	173	165	544	-	544	
	Northbridge	214	319	-	-	533	559	651	38	110	799	-	799	
	Shrewsbury	56	519	12	-	587	63	81	35	116	232	-	232	
	Sutton	930	1,303	202	-	2,435	494	498	265	223	986	-	986	*
	Uxbridge	920	502	-	-	1,422	702	805	62	65	932	-	932	*
	Subtotal	(3,724)	(4,510)	(328)	-	(8,562)	(2,678)	(2,936)	(659)	(828)	(4,423)	-	(4,423)	
12. Merrimack	Amesbury	182	996	59	-	1,237	311	359	13	32	404	-	404	
	Dracut	373	1,696	72	-	2,141	285	348	74	146	568	-	568	
	Dunstable	243	746	32	-	1,021	175	211	39	67	317	-	317	
	Haverhill	472	2,023	35	-	2,530	627	665	50	212	927	-	927	*
	Littleton	479	662	140	-	1,281	183	191	13	163	367	80	447	
	Methuen	309	436	119	-	864	93	99	8	53	160	428	588	
	Westford	190	603	276	-	1,069	340	341	49	260	650	48	698	
	West Newbury	331	1,022	335	-	1,688	152	159	61	216	436	-	436	
	Subtotal	(2,579)	(8,184)	(1,068)	-	(11,831)	(2,166)	(2,373)	(307)	(1,149)	(3,829)	(556)	(4,385)	

TABLE A3-3 AGRICULTURAL LAND USE AND LIVESTOCK AND POULTRY STATISTICS

Basin No. and Name	City/Town	1980 Agricultural Land Use: Cropland Ac.	Hay & Pasture Ac.	Orchards Nurseries Ac.	Cran-berry Ac.	Total Ac.	Livestock 1/: Dairy Number	Dairy AU 2/	Beef AU	Other 3/ AU	Total AU	Poultry 4/ AU	Livestock & Poultry AU	Selected for Detailed Analysis
13. Concord & Sudbury	Chelmsford	198	310	38	-	546	198	227	-	154	381	80	461	
	Concord	868	659	4	-	1,531	537	551	2	321	874	12	886	
	Framingham	208	406	25	-	639	81	79	5	71	155	-	155	
	Hopkinton	85	316	232	-	633	4	3	18	212	233	-	233	
	Marlborough	147	465	52	-	664	66	83	56	158	297	30	327	
	Sudbury	374	485	70	-	929	4	5	5	621	631	-	631	
	Southborough	195	324	29	-	548	303	363	59	40	462	-	462	
	Wayland	225	446	-	-	671	94	132	-	121	253	-	253	
	Westborough	525	627	142	-	1,294	78	96	65	62	223	-	223	
	Subtotal	(2,825)	(4,038)	(592)	-	(7,455)	(1,365)	(1,539)	(210)	(1,760)	(3,509)	(122)	(3,631)	
14. Assabet	Berlin	55	747	96	-	898	313	328	56	126	510	20	530	
	Bolton	319	771	530	-	1,620	28	29	68	125	222	-	222	
	Northborough	67	345	272	-	684	-	-	40	7	47	48	95	
	Stow	182	252	151	-	585	56	64	41	89	194	-	194	
	Subtotal	(623)	(2,115)	(1,049)	-	(3,787)	(397)	(421)	(205)	(347)	(973)	(68)	(1,041)	
15. Shawsheen	Tewksbury	147	415	54	-	616	-	-	-	54	54	-	54	
	Andover	206	159	37	-	402	95	126	10	324	460	-	460	
	Subtotal	(353)	(574)	(91)	-	(1,018)	(95)	(126)	(10)	(378)	(514)	-	(514)	
16. Parker	Georgetown	79	178	8	-	265	250	350	89	132	571	-	571	
	Newbury	695	430	14	-	1,139	252	273	59	111	443	-	443	
	Subtotal	(774)	(608)	(22)	-	(1,404)	(502)	(623)	(148)	(243)	(1,014)	-	(1,014)	
17. Ipswich	Hamilton	42	777	36	-	855	-	-	-	7	7	-	7	
	Ipswich	355	884	125	-	1,364	175	180	29	219	428	-	428	
	N. Andover	220	784	39	-	1,043	309	350	46	232	628	28	656	
	Subtotal	(617)	(2,445)	(200)	-	(3,262)	(484)	(530)	(75)	(458)	(1,063)	(28)	(1,091)	
18. North Coastal	- NONE -													
19. Boston Harbor	- NONE -													
20. Charles	Franklin	173	724	99	-	996	211	243	28	106	377	-	377	
	Medway	103	482	6	-	591	295	368	55	81	504	-	504	
	Millis	88	630	13	-	731	71	69	82	135	286	-	286	
	Sherborn	43	786	34	-	863	18	16	118	209	343	-	343	
	Wrentham	32	837	60	-	929	15	16	30	158	204	45	249	
	Subtotal	(439)	(3,459)	(212)	-	(4,110)	(610)	(712)	(313	(689)	(1,714)	(45)	(1,759)	

TABLE A3-3 - AGRICULTURAL LAND USE AND LIVESTOCK AND POULTRY STATISTICS

Basin No. and Name	City/Town	1980 Agricultural Land Use: Cropland Ac.	Hay & Pasture Ac.	Orchards Nurseries Ac.	Cran-berry Ac.	Total Ac.	Livestock 1/: Dairy Number	Dairy AU 2/	Beef AU	Other 3/ AU	Total AU	Poultry 4/ AU	Livestock & Poultry AU	Selected for Detailed Analysis
21. North	- NONE -													
22. South Coastal	Kingston	2	111	19	246	378	7	5	30	27	62	-	62	
	Plymouth	214	171	1	1,136	1,522	5	5	104	23	132	-	132	
	Subtotal	(216)	(282)	(20)	(1,382)	(1,900)	(12)	(10)	(134)	(50)	(194)	-	(194)	
23. Cape Cod	Barnstable	31	238	5	267	541	31	36	14	138	188	-	188	
	Falmouth	140	215	66	176	597	1	1	8	159	168	-	168	
	Subtotal	(171)	(453)	(71)	(443)	(1,138)	(32)	(37)	(22)	(297)	(356)	-	(356)	
24. Islands	Nantucket	302	236	-	295	833	-	-	26	44	70	-	70	
	Subtotal	(302)	(236)	-	(295)	(833)	-	-	(26)	(44)	(70)	-	(70)	
25. Buzzards Bay & Mt. Hope Bay	Acushnet	132	628	86	68	914	97	117	31	49	197	-	197	
	Carver	101	102	2	2,944	3,149	9	12	3	30	45	-	45	*
	Dartmouth	2,091	1,631	55	51	3,828	1,359	1,659	546	475	2,680	-	2,680	*
	Fairhaven	129	149	4	-	282	402	502	9	33	544	-	544	
	Fall River	10	78	25	-	113	-	-	-	38	38	80	118	
	Rehoboth	2,318	861	4	-	3,183	800	945	705	983	2,633	-	2,633	*
	Rochester	480	613	46	774	1,913	50	61	92	558	711	-	711	
	Swansea	1,426	424	39	-	1,889	439	518	241	73	832	-	832	
	Wareham	-	10	12	1,759	1,781	1	1	3	100	104	-	104	
	Westport	3,229	1,042	16	-	4,287	2,455	3,071	392	706	4,169	296	4,465	*
	Subtotal	(9,916)	(5,538)	(289)	(5,596)	(21,339)	(5,612)	(6,886)	(2,022)	(3,045)	(11,953)	(376)	(12,329)	
26. Taunton	Berkley	651	370	-	2	1,023	35	37	44	156	237	-	237	
	Bridgewater	1,063	1,227	30	12	2,332	1,985	2,318	77	140	2,535	-	2,535	*
	Dighton	648	181	6	-	835	141	155	26	32	213	10	223	
	E. Bridgewater	617	531	12	14	1,174	317	408	30	150	588	-	588	
	Easton	162	503	0	63	728	44	43	151	206	400	-	400	
	Freetown	192	389	2	305	888	68	83	48	101	232	-	232	
	Halifax	1,324	242	9	286	1,861	2	1	50	118	169	40	209	
	Lakeville	657	618	105	127	1,507	52	39	80	444	563	-	563	
	Middleborough	1,120	1,481	21	800	3,422	1,115	1,395	40	115	1,550	62	1,612	*
	Norton	337	92	46	83	558	131	146	28	265	439	-	439	
	Raynham	367	694	12	5	1,078	134	138	49	392	579	-	579	
	Taunton	686	897	4	17	1,604	29	29	35	-	64	-	64	
	W. Bridgewater	844	415	9	-	1,268	464	586	12	238	836	-	836	
	Subtotal	(8,668)	(7,640)	(256)	(1,714)	(18,278)	(4,517)	(5,378)	(670)	(2,357)	(8,405)	(112)	(8,517)	
27. Ten Mile	Attleboro	391	140	-	-	531	70	74	19	150	243	-	243	
	N. Attleboro	884	240	5	-	1,129	254	277	25	98	400	-	400	
	Seekonk	690	367	9	-	1,066	39	45	35	264	344	28	372	
	(Subtotal)	(1,965)	(747)	(14)	-	(2,726)	(363)	(396)	(79)	(512)	(987)	(28)	(1,015)	
Total 27 Basins		106,304	159,603	11,568	9,430	286,905	73,068	80,974	13,032	23,926	117,932	5,221	123,153	

River Basins

Massachusetts has been divided into 27 basins for Water Resources Planning by the Massachusetts Water Resources Commission. All cities and towns of Massachusetts have been assigned to the particular basin which contains the largest proportion of the community's area. The town of Paxton, for example, drains into three basins, the Chicopee, Nashua and French and Quinebaug; but as more of the town drains into the Chicopee Basin, Paxton has been assigned to this basin. Figure A3-1 presents the hydrologic boundaries of the 27 basins, the municipalities selected to represent each basin, and the 49 municipalities selected for detailed analysis. Table A3-4 lists the 27 Massachusetts River Basins and the number of municipalities in each basin.

Selection of Municipalities for Detailed Analysis

Table A3-5 lists the 49 municipalities which have been selected for detailed analysis. Two criteria have been developed to select these municipalities:

1. The community has 900 or more Animal Units of livestock.
2. Or a community has 2,500 or more acres of agricultural land as mapped in this study.

These 49 municipalities contain 146,000 acres of agricultural land, hayland pasture, cropland, cranberries, orchards, and nurseries, which is 51 percent of the agricultural land in the 177 cities and towns selected earlier in the study and approximately 44 percent of the total agricultural land in Massachusetts. Also, these 49 municipalities contain approximately 56 percent of the total livestock and poultry in the 177 cities and towns.

Table A3-6 lists those river basins (from the listing of 27 basins) in which agriculture has little or no effect on water quality.

Table A3-4 - LIST OF MASSACHUSETTS RIVER BASINS AND NUMBERS OF CITIES AND TOWNS ASSIGNED TO EACH BASIN

Basin Number & Name	Number of Cities & Towns within this Basin	Number of Cities & Towns of the AWQS Study Area within this Basin	Number of Cities & Towns Selected for Detailed Analysis within this Basin
1. Hoosic	8	5	3
2. Housatonic	17	15	4
3. Deerfield	14	10	5
4. Westfield	18	9	3
5. Farmington	3	1	0
6. Connecticut Valley	27	21	11
7. Millers	9	5	0
8. Chicopee	22	18	8
9. French & Quinebaug	10	7	5
10. Nashua	19	15	1
11. Blackstone	14	7	2
12. Merrimack	15	8	1
13. Concord & Sudbury	12	9	0
14. Assabet	8	4	0
15. Shawsheen	5	2	0
16. Parker	3	2	0
17. Ipswich	10	3	0
18. North Coastal	16	0	0
19. Boston Harbor	31	0	0
20. Charles	18	5	0
21. North	7	0	0
22. South Coastal	3	2	0
23. Cape Cod	15	2	0
24. Islands	8	1	0
25. Buzzards Bay & Mt. Hope Bay	14	10	4
26. Taunton	21	13	2
27. Ten Mile	4	3	0
Totals	351	177	49

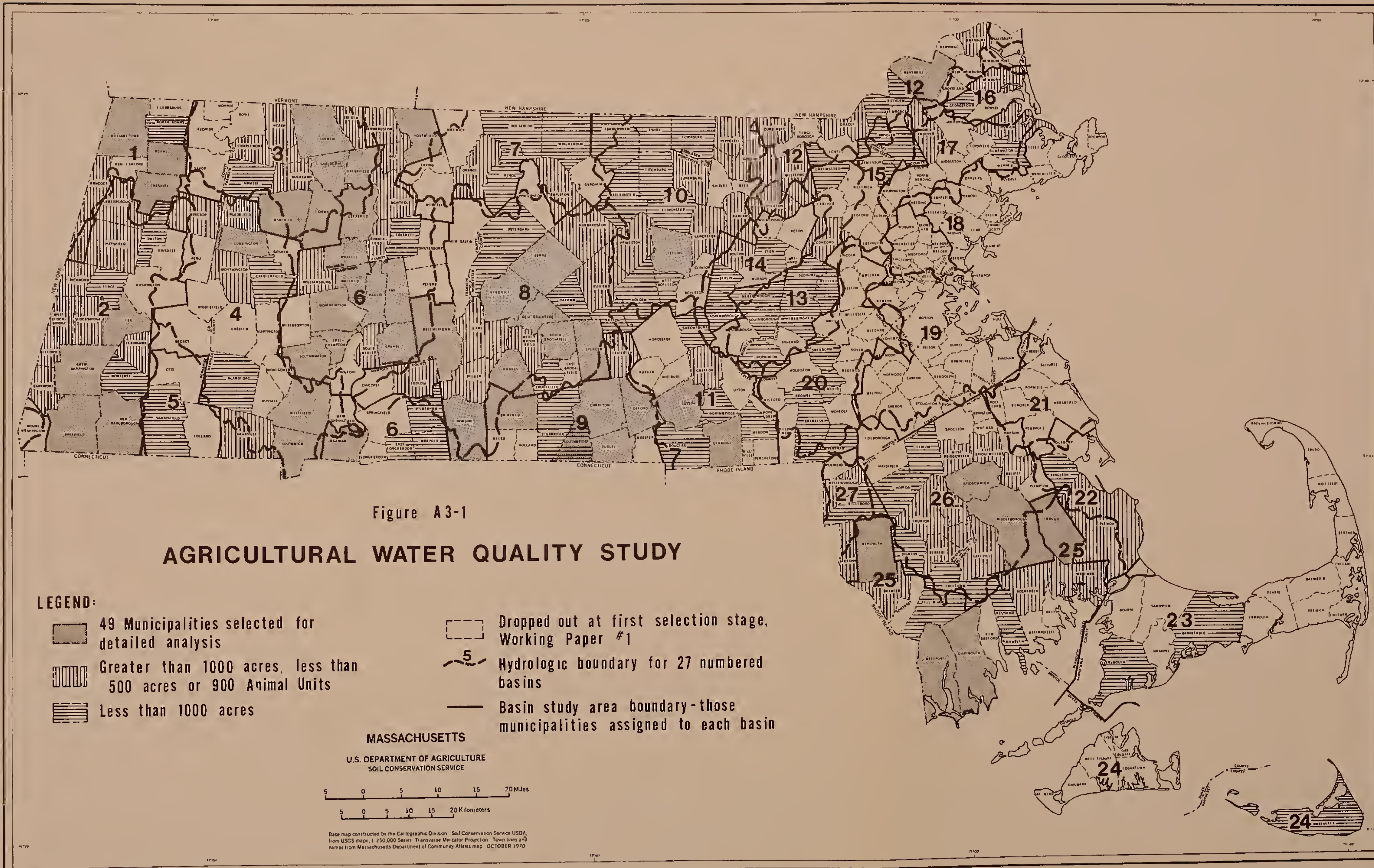


Figure A3-1

AGRICULTURAL WATER QUALITY STUDY

TABLE A3-5 - LIST OF MUNICIPALITIES SELECTED FOR DETAILED STUDY

County	Municipality	County	Municipality
Berkshire	Adams	Worcester	Barre
	Cheshire		Charlton
	Great Barrington		Dudley
	Lee		Hardwick
	New Marlborough		New Braintree
	Sheffield		North Brookfield
	Williamstown		Oxford
			Southbridge
Franklin	Ashfield		Spencer
	Colrain		Sterling
	Conway		Sutton
	Deerfield		Uxbridge
	Greenfield		Warren
	Northfield		
	Shelburne	Essex	Haverhill
	Whately		
		Bristol	Dartmouth
Hampshire	Amherst		Rehoboth
	Belchertown		Westport
	Cummington		
	Easthampton	Plymouth	Bridgewater
	Granby		Carver
	Hadley		Middleborough
	Hatfield		
	Northampton		
	Southampton		
Hampden	Agawam		
	Brimfield		
	Monson		
	Southwick		
	Westfield		

TABLE A3-6 - LIST OF MASSACHUSETTS RIVER BASINS IN WHICH AGRICULTURE HAS LITTLE OR NO EFFECT ON WATER QUALITY 1/

Basin Number and Name	Number of Cities and Towns Within This Basin
5. Farmington	3
18. North Coastal	16
19. Boston Harbor	31
20. Charles	18
21. North	7
23. Cape Cod	15
24. Islands	8
Total	98

1/ In these basins there is essentially little or no agriculture.

Chapter A4. REPORTING AREAS

Where possible, information developed for this study is presented by reporting area. The five reporting areas selected are the most agricultural regions in the state. These areas are:

1. Hoosic and Housatonic Rivers

2. Connecticut River Valley

3. Chicopee River

4. Central - includes the French, Quinebaug, Blackstone, Nashua, and Merrimack Rivers drainage areas in the state

5. Southeastern - includes the Taunton, South Coastal, Buzzards Bay, and Narragansett Bay drainage areas

A separate chapter is included in this appendix for each of the reporting areas.

Within each reporting area information is presented for the municipalities which were selected for detailed analysis earlier in the study. These are the cities and towns with the highest concentration of agriculture in the state and should give an indication of the impacts of agriculture on water quality. See Table A4-1.

Erosion

Sheet and rill erosion estimates were made for all the agricultural land in the selected municipalities. Working Paper #3, Erosion Estimates on Agricultural Land, included as Chapter A13 in this appendix, presents background information on the methodology used.

Sheet and rill erosion was estimated, using the Universal Soil Loss Equation, for all agricultural land in the 49 selected municipalities. Results of these estimates are presented in Chapters A5 to A9.

From this work it was found that in general only cultivated cropland has excessive sheet and rill erosion. Excessive erosion rates are defined as those that exceed the T Factor, the maximum tolerable soil loss, or contribute to downstream water quality problems. As hayland, pasture, and orchards usually have permanent established vegetation, expected erosion rates on these types of agricultural land are low and seldom contribute to downstream water quality problems. However, streambank erosion in hayland, pastures, and orchards can occasionally contribute to downstream problems especially in western Massachusetts.

In the Massachusetts Water Resources Study, completed in 1978, streambank erosion was estimated at 490,500 tons for the 4,538,000 acres of the Connecticut River, Central, and Coastal Regions. These three regions contain approximately 87 percent of the area of Massachusetts. The National Resource

TABLE A4-1 - LIST OF SELECTED MUNICIPALITIES IN EACH REPORTING AREA

1. HOOSIC AND HOUSATONIC

Hoosic	Housatonic
Adams	Great Barrington
Cheshire	Lee
Williamstown	New Marlborough
	Sheffield

2. CONNECTICUT RIVER VALLEY

Connecticut River Valley	Lower Deerfield	Lower Westfield
Agawam	Ashfield	Southwick
Amherst	Colrain	Westfield
Deerfield	Conway	Cummington 1/
Easthampton	Greenfield	
Granby	Shelburne	
Hadley		
Hatfield		
Northampton		
Northfield		
Southampton		
Whately		

3. CHICOPEE

Chicopee
Barre
Belchertown
Hardwick
Monson
New Braintree
North Brookfield
Spencer
Warren

1/ Cummington is included with the Lower Westfield municipalities because it is in the Westfield Basin.

TABLE A4-1 - LIST OF SELECTED MUNICIPALITIES IN EACH REPORTING AREA (cont.)

4. CENTRAL

French and Quinebaug	Blackstone	Nashua and Merrimack
Brimfield	Sutton	Sterling
Charlton	Uxbridge	Haverhill
Dudley		
Oxford		
Southbridge		

5. SOUTHEASTERN MASSACHUSETTS

Buzzards Bay and Mt. Hope Bay	Taunton
Carver	Bridgewater
Dartmouth	Middleborough
Rehoboth	
Westport	

Inventory, conducted by the SCS, has developed 1980 information nationwide on streambank and gully erosion based on a sampling of 100 acre sample areas, which constitute one percent of each state's area. For Massachusetts the estimated average annual erosion in streambanks is 140,000 tons and in gullies it is 26,000 tons from this inventory. These two annual estimates for streambank erosion, 490,500 for 87 percent of the state and 140,000 for the entire state do not compare favorably.

Further investigation would possibly predict an annual streambank erosion estimate between these two values. Presently there is about 350,000 acres in agricultural land use or about seven percent of the total state area. The amount of streambank erosion associated with agricultural land would probably be more than seven percent of the statewide total.

The statewide annual estimate for gully erosion is a relatively low figure and indicates that this type of erosion is relatively insignificant in the state. Possibly more detailed analysis would produce a higher value for this type of erosion but it is doubtful that gully erosion would ever be considered more than a site specific or local problem.

Streambank and gully erosion is a factor in erosion on agricultural land but study restraints have limited our investigation of these types of erosion. Evidence of gully and streambank erosion is obvious to an on-site viewer while sheet erosion seldom is. Sheet and rill erosion can be considered to be the primary source of erosion on agricultural lands.

Erosion on agricultural lands adds other pollutants to water resources besides sediment. These other pollutants include organic materials such as manure, carbonaceous matter, and living organisms; pesticides, herbicides, and other agricultural chemicals and plant nutrients such as nitrogen and phosphorous. To develop an idea of the effect of erosion on downstream water resources, estimates of total phosphorous associated with sediment were developed. The methodology for this was developed in order to produce a rough guide for determining excessive erosion rates from a water quality perspective. We already have the "T" factor, maximum tolerable soil loss in tons per acre per year, which is a guide used for soil conservation objectives. In addition, the Plan of Work requested that unacceptable levels of soil loss be defined based on the soil erosion contribution to nutrient levels in water resources.

Chapter A5. REPORTING AREA 1 - HOOSIC AND HOUSATONIC RIVERS

This reporting area consists of two river basins of the state total of 27 river basins; namely, the drainage area of the Hoosic and the Housatonic Rivers. As indicated earlier in this appendix, 25 cities and towns, all in Berkshire County, have been assigned to this reporting area. These municipalities have a majority of their area within the contributing drainage areas of these two river basins.

Five towns, Clarksburg, Hinsdale, Mt. Washington, New Ashford, and Washington, were eliminated at the first selection stage because of their small amount of agriculture. These towns are primarily forestland as indicated in Table A5-1, based on 1972 land use data. Updated agricultural land use data would probably indicate even lower agricultural acreage as was the case for 22 Berkshire County cities and towns which lost an average 24 percent of their 1972 agricultural land by 1980 (Table A3-1).

Seven of the remaining 20 municipalities were selected for detailed analysis. Erosion on agricultural land is the first of the analyses.

Erosion

Sheet and rill erosion estimates were computed for the agricultural land in the seven selected municipalities in the reporting area. Summaries of these estimates were first presented in Working Paper #3, which is included in this appendix. As Table A5-2 indicates, the estimated erosion rates on hayland pasture, orchards, and nurseries are low. Erosion from these types of agricultural land contribute little to water quality problems in the reporting area. The permanent vegetative cover characteristic of these types of agricultural land is usually part of the solution for an erosion problem.

On the other hand, cropland in the reporting area does have serious erosion problems accompanied by downstream water quality impacts. Table A5-3 presents estimated erosion and associated total phosphorus from cropland for the seven selected towns. The average erosion rates for each town are higher than three tons per acre per year, the "T" factor or maximum tolerable soil loss from a soil conservation perspective for most soils in Massachusetts.

The estimated increase in total phosphorus concentration is calculated using the methodology presented in Working Paper #3. In that paper, unacceptable levels of erosion, for a given acreage of cropland in a given watershed area, were defined as those that raised the average annual total phosophorus concentration by 0.010 mg/l. As presented in Table A5-3, Great Barrington and New Marlborough have sufficiently low average erosion rates on their cropland, with the result that they do not exceed these criteria for total phosphorus increase in their water resources.

Cropland erosion is one source of pollutants from agricultural land in water resources. Other sources will also be considered and there is the possibility that the combination of pollutants from various agricultural sources may be sufficient to cause unacceptable downstream water quality problems.

TABLE A5-1 - 1972 Agricultural and Forest Land Use Data for Towns Eliminated at the First Selection Stage 1/

Town	Agricultural Land		Forest Land		Total Land & Water Area (Acres)
	Acres	Percentage of Total Area	Acres	Percentage of Total Area	
Clarksburg	486	6.0	6,345	77.8	8,160
Hinsdale	946	6.8	10,323	74.0	13,830
Mt. Washington	374	2.6	13,658	95.4	14,324
New Ashford	537	6.3	7,583	88.3	8,592
Washington	397	1.6	22,317	90.5	24,651

1/ MacConnell, William P. and William Wiedwiedz, Remote Sensing 20 Years of Change in Berkshire County, Massachusetts 1952-1972, Mass. Agricultural Experiment Station, U. of Mass., Amherst, MA, 1975.

Hoosic and Housatonic Rivers Reporting Area

TABLE A5-2 - Summary of Erosion Estimates for Hayland, Pasture, Orchards, and Nurseries in the Seven Most Agricultural Municipalities

Item	Units	Quantity
Hayland Area - Ac		4,761
" Annual Erosion	Tons	1,817
" Annual Average Erosion Rate	Tons/Ac	0.4
Pasture Area - Ac		10,971
Annual Erosion - Tons		4,983
Annual Average Erosion Rate	Tons/Ac	0.5
Orchards and Nurseries Area - Ac		218
Annual Erosion - Tons		100
Annual Average Erosion Rate	Tons/Ac	0.5
Total Area - Ac		15,950
Annual Erosion - Tons		6,900
Annual Average Erosion rate	Tons/Ac	0.4

TABLE A5-3 - Estimated Annual Erosion and Associated Total Phosphorus from Cropland

Basin	Town	Cropland Ac.	Erosion Tons	Erosion Rate Tons/Ac.	Ave. Total Phosphorus Conc. in Runoff from Cropland Erosion 1/ mg P_t/1	Ave. Total Phosphorus Conc. in Water Resources from Cropland Erosion 2/ mg P_t/1
Hoosic	Adams	556	7,126	12.8	0.56	0.021
"	Cheshire	653	10,731	16.4	0.69	0.025
"	Williamstown	1,223	11,592	9.5	0.34	0.014
Housatonic	Gt. Barrington	1,365	6,310	4.6	0.17	0.008
	Lee	1,010	5,455	5.4	0.23	0.013
	New Marlborough	1,108	8,334	7.5	0.27	0.010
	Sheffield	3,719	13,058	3.5	0.13	0.015

1/ This term designated J in Working Paper #3. Values here assume 1.5 lbs. of total phosphorus per ton of sediment and average annual runoff of 22 inches.

2/ This term is J x acres of cropland/total watershed area in acres and can be added to P_tt conc. on annual basis from other sources.

Animal Waste

The animal numbers presented earlier were used to estimate manure and certain pollutant or nutrient quantities produced by livestock and poultry in the selected towns. Values for specific livestock or poultry from Table 4-1, Daily Production and Composition of Livestock Manure, Agricultural Waste Management Field Manual, an SCS publication, were used. These estimates are presented for dairy cattle and for total livestock and poultry in Tables A5-4 and A5-5.

Other water pollutants originating from animal manure include chemicals such as sodium, manganese and iron, organic material, and living organisms including bacteria such as the fecal coliform group. In the Westport River Rural Clean Water Project in eastern Massachusetts, the most serious pollutant problem is bacteria from animal waste and other sources polluting shellfish beds. These other pollutants could be estimated using average values but the usefulness of the resulting numbers is limited. The nitrogen, phosphorus, and potassium estimates have more value as they can be used to determine how much of a crop total fertilizer needs can be supplied from animal waste.

The number of dairy animals in the seven towns surveyed is approximately 8300 animal units or approximately 69 percent of the total dairy animal units in the 20 cities and towns selected earlier for the reporting area; while the number of total livestock and poultry in the seven towns analyzed, approximately 10,000 animal units, is about 66 percent of the 20 city and town total. Only poultry operations with more than 10 animal units, which is 2500 chickens or 1000 turkeys, were included in the survey.

As Tables A5-4 and A5-5 show, substantial amounts of manure are generated in the area. The conventional method of disposal of this material is land spreading. To minimize adverse downstream water quality problems and to maximize benefits to the soil requires consideration of application methods, the livestock or poultry involved, and land, crop and climate factors.1/

The manner in which constituents of manure are transported from areas where manure has been spread or stored depend initially on the degree of solubility of the forms in which these constituents are found. For example, the nitrate form of nitrogen is readily soluble and can be expected to be transported from a site in surface runoff or in any other way water leaves the site such as seepage through the ground. In a surface runoff event, soluble forms of nitrogen would be readily lost, dissolved in the runoff, while relatively non-soluble forms of nitrogen would only leave if solid or particulate matter were carried off. Phosphorus, being relatively non-soluble, mainly leaves with the sediment and other solid material it is attached or associated with. If these solid materials are not transported away, very little phosphorus can be expected to leave. Reducing erosion on a field where manure is spread will have a corresponding and significant reduction in phosphorus loss. Erosion reduction would reduce nitrogen loss on this field but not to the significant degree as with phosphorus.

1/ Gilbertson, C.B. et al., Animal Waste Utilization on Cropland and Pasture Land, A Manual for Evaluating Agronomic and Environmental Effects. USDA Utilization Research Report 1806, EPA-600/2-79-059, USDA-SEA EPA-ORD, Washington, D.C., Oct. 1979.

TABLE A5-4 - Annual Dairy Manure and Pollutant/Nutrient Production for Selected Towns

Town	Animal Units	Manure Tons	Manure Dry Solids Tons	Pollutant/Nutrient BOD_5	Pollutant/Nutrient Total Nitrogen	Pollutant/Nutrient Total Phosphorus	Pollutant/Nutrient Total Potassium
				1000 pounds			
Adams	995.4	15429.	/1689.	508.6	134.4	25.1	72.7
Cheshire	1350.0	20925.	/2291.	689.9	182.3	34.0	98.6
Williamstown	1553.2	24075.	/2636.	793.7	209.7	39.1	113.4
Gt. Barrington	443.1	6868.	/752.	226.4	59.8	11.2	32.4
Lee	755.2	11706.	/1282.	385.9	102.0	19.0	55.1
New Marlborough	217.5	3371.	/369.	111.1	29.4	5.5	15.9
Sheffield	2960.6	45889.	/5024.	1512.9	399.7	74.6	216.1
Totals	8275.	128263	14043	4228.5	1117.3	208.5	604.2
% Dairy is of Total Livestock and Poultry Production	82.	87.	78	80.	81	73	58

BOD_5 - 5 day biochemical oxygen demand is a measure of the oxygen used in pounds per year in this table, in water in decomposing organic material by micro-organisms and by chemical reaction of the sample materials. Test is usually run for 5 days for traditional and testing cost considerations.

At a typical spreading rate of 20 tons/acre, 6410 acres are needed for disposal of the 7 town total of manure.

TABLE A5-5 - Annual Livestock and Poultry Manure and Pollutant/Nutrient Production for Selected Towns

Town	Animal Units	Manure		Pollutant/Nutrient			
		Tons	Dry Solids Tons	BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
				1000 pounds			
Adams	1,109.1	16,657	1,908	570.8	151.1	29.2	82.5
Cheshire	1,467.2	22,103	2,586	753.8	197.6	39.0	109.0
Williamstown	2,047.7	29,183	3,753	1,104.7	290.1	64.9	159.3
Gt. Barrington	621.8	8,612	1,227	318.8	82.3	18.4	48.4
Lee	1,079.7	15,155	1,958	562.2	148.5	31.0	83.2
New Marlborough	455.	5,774	927	234.8	61.5	19.5	36.9
Sheffield	3,306.1	49,637	5,717	1,710.1	449.9	88.2	246.1
Totals	10,086.6	147,121	18,076	5,255.2	1,381.0	285.2	1,050.6

BOD_5 - 5-day biochemical oxygen demand is a measure of the oxygen used, in pounds per year in this table, in water in decomposing organic material by micro-organisms and by chemical reaction of the sample materials. Test is usually for 5 days for traditional and testing cost considerations.

An estimate of phosphorus increase in water resources is provided in Table A5-6, Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry for Selected Municipalities. Estimates for each community were developed in a similar manner and are based on the same assumptions and so are most useful in comparisons between communities. These values can be added to the average total phosphorus concentration in water resources from cropland erosion values found on Table A5-3 to get an approximate impact on annual phosphorus concentration from agriculture in the water resources on a town-by-town basis.

Information on collection, storage, and disposal of animal manure for 19 dairy operations and seven other livestock operations in the seven towns surveyed was gathered. The seven other livestock operations were all small beef cattle farms. These farms were selected by picking every fourth farm from a listing of all the livestock operations in the seven towns. Table A5-7 summarizes this information. There are a total of 105 livestock operations in the 49 cities and towns surveyed statewide of which 68 are dairy and 37 are other livestock, which could include beef, swine, horses, ponies, sheep, and goats.

This information forms the basis of our estimates of what practices are necessary to minimize effects on water quality from livestock.

There are four poultry farms which exceed the minimum criteria for inclusion in this study (at least 10 animal units which is 1,000 turkeys or 2,500 chickens) in the 20 municipalities selected for analysis in this reporting area. There are few additional flocks which meet this criteria in the five towns which were eliminated at the first selection stage from this reporting area because of too little agriculture.

Our information gathering on actual poultry operations was concentrated in the Chicopee River Reporting Area and in the Central Reporting Area which includes the French, Quinebaug, Blackstone, Nashua, and Merrimack Rivers in Massachusetts. The major presentation on poultry will be found in the Chicopee River Reporting Area section. A few general comments can be presented here, however, concerning poultry operations. Most poultry farms use housing which allows manure storage under cover from the elements. Poultry manure collection and storage generally present few problems for water quality. The major concern centers on disposal of poultry manure. All the poultry operations surveyed spread manure on agricultural land, either their own or that of neighboring farms. However, over 65 percent of these operations spread during the winter. Spreading manure on snow or frozen ground usually results in excessive runoff of this manure when thaws occur. This results in water quality problems downstream and an economic loss to the farmer in the fertilizer and other values this manure would add to the field where originally spread.

Massachusetts Agricultural Water Quality Study

Hoosic and Housatonic Rivers

TABLE A5-6 - Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry Manure for Selected Municipalities.

Town	Town Total Area Acres	Annual Total Phosphorus Generated 1,000 lbs. 1/	Average Added Total Phosphorus in Water Resources on Yearly Basis 2/ mg/l
Adams	14,520	29.2	0.008
Cheshire	17,856	39.0	0.009
Williamstown	30,016	64.9	0.008
Gt. Barrington	29,088	18.4	0.003
Lee	17,376	31.0	0.007
New Marlborough	30,260	14.5	0.002
Sheffield	31,417	88.2	0.011
Totals	170,533	285.2	-
Average	-	-	0.007

1/ From Table A5-5.

2/ Computation based on annual runoff of 22 inches (1.83 feet), estimated 2% of total phosphorus reaches water resources.

$$\text{Added } P_t \text{ (mg/l)} = \frac{0.02 \text{ Wt } P_t \times 453600 \text{ mg/lb}}{\text{Town Area in Acres} \times 1.83 \text{ ft.} \times 1.234 \times 10^6 \text{ liters/Ac. Ft.}}$$

$$= 0.004 \text{ Wt } P_t\text{/Acres.}$$

Massachusetts Agricultural Water Quality Study

Hoosic and Housatonic Rivers

TABLE A5-7 - Summary of Livestock Operations Manure Handling Survey Data.

Type Operation	Number Range of Livestock	Number of Farms Inventoried	Average Size of Farms Inventoried	Average Number of Dairy Cattle	Average Number of Farm Livestock	Pasture Usage Summer Only	Barn Type: Stanchion	Barn Type: Free Stall or Loose Housing	Manure Storage: Spread Daily	Manure Storage: Use Stacks or Piles	Manure Storage: Adequate Storage Facility	Manure Spreading: On Cropland	Manure Spreading: On Hayland	Manure Spreading: On Pasture	Distribute 25% or More in Winter	Remarks
	Animal Units 1/		Ac.	Animal Units	Animal Units	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	
Small dairy herds	10 to 50	2	80	16	19	2	-	-	1	2	0	1	1	1	1	All young stock.
Medium dairy herds	50 to 150	9	310	110	113	7	7	2	4	7	1	6	8	1	4	Stacks on steep slopes, runoff problems noted on fields, barnyard runoff problems noted, inadequate milkouse disposal noted.
Large dairy herds	Over 150	8	560	264	265	8	3	5	3	6	0	7	5	1	5	Runoff problems noted on fields, barnyard runoff problems noted, inadequate milkhouse disposal noted.
Other livestock mostly beef	Over 10	7	150	-	29	4	-	7	1	4	1	0	4	5	0	No runoff problems apparent.

1/ See Table A3-2 Animal Units.

Chapter A6. REPORTING AREA 2 - CONNECTICUT RIVER VALLEY

The Connecticut River drainage in Massachusetts has been divided into six individual basins: Deerfield River, Westfield River, Farmington River, Connecticut Valley, Millers River, and Chicopee River.

This chapter concentrates on the Connecticut Valley basin and the lower portions of the Deerfield River and Westfield River basins. These last two basins are most highly agricultural in their downstream portions which border the Connecticut River Valley basin. Their upstream areas are heavily forested and have relatively little agriculture. The Chicopee River basin has been designated Reporting Area 3 and information on this basin is presented in Chapter A7. As the Farmington River and Millers River basins contain too little agriculture, they will not be considered further.

The five basins which initially comprised the Connecticut River Valley reporting area contains 71 cities and towns. At the first selection stage, presented in Working Paper #1, 25 cities and towns were eliminated because of the small amount of agriculture they contain. Highly urbanized cities dropped at this stage include Springfield and Holyoke. Examples of lowly populated but heavily forested towns dropped are Tolland and Monroe. Table A6-1, 1972 Agricultural, Urban, and Forest Land Use for the 25 Cities/Towns Eliminated at the First Selection Stage, compares acreage of agricultural land with forest and urban land acreage.

Nineteen of the remaining 46 municipalities were selected for detailed analysis. Erosion on agricultural land is the initial analysis.

Erosion

Sheet and rill erosion estimates were computed for the agricultural land in the 19 selected municipalities in the reporting area. Summaries of these estimates were first presented in Working Paper #3. As Table A6-2 indicates, the expected erosion rates on hayland, pasture, orchards, and nurseries are low. Erosion from these types of agricultural land, essentially farm lands with permanent vegetation, contributes little to water quality problems. On the other hand cropland in the reporting area does have serious erosion problems accompanied by downstream water quality impacts. Table A6-3 presents estimated erosion and associated total phosphorus from cropland for the 19 selected cities and towns. The annual average erosion rates on cropland for each town range from 1.7 tons per acre in Hadley to 18 tons per acre in Colrain. In Hadley and other Connecticut Valley towns, the lands used for cropland include nearly level soils such as Hadley soil which formed on Connecticut River flood plains and other major river flood plains in New England. Cropland in Colrain and other hill towns is often on moderately or steeply sloping land and erosion rates often exceed "T" values, the maximum tolerable soil loss from a soil conservation perspective. Thirteen of the 19 municipalities have average erosion rates which exceed 3 tons per acre per year which is the "T" value for most soils in Massachusetts.

Table A6-1. 1972 Agricultural, Urban, and Forest Land Use Data for Cities/Towns Eliminated at the First Selection stage[1/]

Basin	City/Town	Agricultural Land Ac.	Agricultural Land % of Total Area	Urban Land Ac.	Urban Land % of Total Area	Forest Ac.	Forest % of Total Area	Total Land & Water Ac.
Deerfield	Florida	638	4.1	371	2.4	13,340	86.2	15,468
	Monroe	100	1.4	96	1.4	6,437	92.9	6,928
	Rowe	492	3.2	338	2.2	13,520	87.5	15,460
	Savoy	843	3.7	204	0.9	20,783	90.7	22,904
Westfield	Becket	389	1.3	1,769	5.8	25,764	85.0	30,326
	Chester	717	3.0	430	1.8	21,555	90.9	23,716
	Goshen	352	3.1	469	4.1	10,088	87.9	11,476
	Huntington	792	4.6	814	4.8	14,484	84.9	17,068
	Middlefield	935	5.9	192	1.2	14,176	89.7	15,810
	Montgomery	438	4.3	221	2.2	9,178	90.5	10,144
	Peru	139	0.8	327	2.0	15,577	93.2	16,708
	Russell	106	1.0	565	5.1	9,863	88.7	11,116
	West Springfield	936	8.3	4,541	40.5	4,056	36.2	11,212
Farmington	Otis	394	1.6	1,226	5.0	19,316	79.3	24,364
	Tolland	246	1.2	296	1.4	18,634	89.4	20,848
Conn. Valley	Holyoke	756	5.2	4,636	31.7	6,858	46.9	14,616
	Longmeadow	332	5.4	2,605	42.7	2,240	36.7	6,100
	Pelham	303	1.9	282	1.8	14,012	87.4	16,041
	Shutesbury	215	1.3	272	1.6	15,967	92.9	17,188
	Springfield	309	1.4	14,171	66.4	4,878	22.9	21,344
	Westhampton	969	5.7	552	3.2	15,269	89.2	17,122
Millers	Erving	299	3.3	823	9.1	7,445	82.1	9.064
	Gardner	707	4.8	2,720	18.4	9,623	65.0	14,814
	Warwick	967	3.7	79	0.3	23,956	92.6	25,874
	Wendell	505	2.3	86	0.4	20,112	93.0	21,620

1/ MacConnell, William P., Remote Sensing: 20 Years of Change in Franklin County Massachusetts, 1952-1972, Mass. Agricultural Experiment Station, Univ. of Mass., Amherst, MA, 1975, and 4 other similar publications covering Hampshire, Berkshire, Hampden, and Worcester Counties.

Table A6-2. Summary of Erosion Estimates for Hayland, Pasture, Orchards and Nurseries for the 19 Most Agricultural Municipalities.

Item	Units	Quantity
Hayland - Area	Ac.	10,923
Annual Erosion	Tons	3,142
Annual Average Erosion Rate	Tons/Ac.	0.3
Pasture - Area	Ac.	17,643
Annual Erosion	Tons	8,680
Annual Average Erosion Rate	Tons/Ac.	0.5
Orchards and Nurseries - Area	Ac.	1,582
Annual Erosion	Tons	860
Annual Average Erosion Rate	Tons/Ac.	0.5
Total	Ac.	30,148
Annual Erosion	Tons	12,682
Annual Average Erosion Rate	Tons/Ac.	0.4

TABLE A6-3 - Estimated Annual Erosion and Associated Total Phosphorus from Cropland

Basin	Municipality	Cropland Ac.	Erosion Tons	Erosion Rate Tons/Ac.	Ave. Total Phosphorus Conc. in Runoff from Cropland Erosion 1/ mg P_t/1	Ave. Total Phosphorus Conc. in Water Resources from Cropland Erosion 2/ mg P_t/1
Deerfield	Ashfield	344	5,500	16.1	0.61	0.008
	Colrain	994	17,848	18.0	0.65	0.023
	Conway	389	5,316	13.7	0.52	0.008
	Greenfield	1,069	4,036	3.8	0.17	0.012
	Shelburne	627	8,200	13.1	0.55	0.022
Westfield	Cummington	368	4,226	11.5	0.50	0.012
	Southwick	2,008	9,878	4.9	0.20	0.020
	Westfield	1,709	4,090	2.4	0.09	0.005
Conn. Valley	Agawam	1,989	7,742	3.9	0.16	0.021
	Amherst	1,397	6,188	4.4	0.19	0.015
	Deerfield	3,469	12,158	3.5	0.14	0.023
	Easthampton	853	5,423	6.4	0.32	0.031
	Granby	990	3,294	3.3	0.14	0.008
	Hadley	4,595	7,927	1.7	0.07	0.020
	Hatfield	2,987	5,566	1.9	0.09	0.026
	Northampton	2,298	4,572	2.0	0.08	0.008
	Northfield	2,223	7,351	3.3	0.13	0.013
	Southampton	895	2,250	2.5	0.10	0.005
	Whately	1,662	3,036	1.8	0.08	0.010

1/ This term designated J in Working Paper #3. Values here assume 1.5 lbs. of total phosphorus per ton of sediment and average annual runoff of 22 inches.

2/ This term is J x acres of cropland/total watershed area in acres, and can be added to P_t conc. on an annual basis from other sources.

The estimated increase in total phosphorus concentration is calculated using the methodology presented in Working Paper #3. In that paper, unacceptable levels of erosion, for a given acreage of cropland in a given watershed area, were defined as those that raised the average annual total phosphorus concentration by 0.010 milligrams per liter.

Two towns, Ashfield and Conway, have average cropland erosion rates greatly in excess of 3 tons per acre per year, "T" factor for most Massachusetts soils, but because they have so little acreage in cropland they do not exceed the total phosophorus increase criteria. The other extreme for this list of municipalities are Whately, Hatfield, and Hadley, which have average erosion rates significantly below 3 tons per acre per year, but have so much acreage in cropland that they do exceed the total phosphorus increase criteria.

Cropland erosion is one source of pollutants in water resources which originates from agricultural land. Other agricultural sources of water pollution, such as animal wastes, may be combined with erosion products with the result that unacceptable downstream water quality problems may develop.

Animal Waste

The animal numbers presented earlier were used to estimate manure and certain pollutant or nutrient quantities produced by livestock and poultry in the selected towns. Values for specific livestock or poultry from Table 4-1, Daily Production and Composition of Livestock Manure, Agricultural Waste Mangement Field Manual, an SCS publication, were used. These estimates are presented for dairy cattle and for total livestock and poultry in Tables A6-4 and A6-5.

The number of dairy animals in the 19 cities and towns surveyed is approximately 19,300 animal units or approximately 71 percent of the total dairy animal units in the 46 cities and towns selected earlier for the reporting area; while the number of total livestock and poultry in the seven towns analyzed, approximately 23,900 animal units, is about 67 percent of the 46 city and town total. Only poultry operations with more than 10 animal units, equal to 2,500 chickens or 1,000 turkeys, were included in the survey.

As Tables A6-4 and A6-5 show, substantial amounts of manure are generated in the area. The conventional method of disposal of this material is land spreading. To minimize adverse downstream water quality problems and to maximize benefits to the soil requires consideration of application methods, the livestock or poultry involved, and land, crop and climate factors. [1/]

1/ Gilbertson, C.B. et al., Animal Waste Utilization on Cropland and Pasture Land, A Manual for Evaluating Agronomic and Environmental Effects. USDA Utilization Research Report 1806, EPA-600/2-79-059, USDA-SEA EPA-ORD, Washington, D.C., Oct. 1979.

TABLE A6-4 - Annual Dairy Manure and Pollutant/Nutrient Production for Selected Municipalities

Municipality	Dairy Animal Units	Manure Tons/Dry Solids Tons		Pollutant/Nutrient BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
				1000 pounds			
Ashfield	1702.0	26381./2888.		869.7	229.8	42.9	124.2
Colrain	881.8	13668./1496.		450.6	119.0	22.2	64.4
Conway	766.0	11873./1300.		391.4	103.4	19.3	55.9
Greenfield	727.4	11275./1234.		371.7	98.2	18.3	53.1
Shelburne	1135.3	17597./1927.		580.1	153.3	28.6	82.9
Cummington	1061.7	16456./1802.		542.5	143.3	26.8	77.5
Southwick	1069.8	16582./1815.		546.7	144.4	27.0	78.1
Westfield	1101.0	17066./1868.		562.6	148.6	27.7	80.4
Agawam	167.0	2588./283.		85.3	22.5	4.2	12.2
Amherst	923.6	14316./1567.		472.0	124.7	23.3	67.4
Deerfield	2158.9	33463./3664.		1103.2	291.5	54.4	157.6
Easthampton	987.3	15303./1675.		504.5	133.3	24.9	72.1
Granby	604.8	9374./1026.		309.1	81.6	15.2	44.2
Hadley	2062.6	31970./3500.		1054.0	278.5	52.0	150.6
Hatfield	335.9	5206./570.		171.6	45.3	8.5	24.5
Northampton	455.0	7052./772.		232.5	61.4	11.5	33.2
Northfield	1969.0	30520./3341.		1006.2	265.8	49.6	143.7
Southampton	1024.6	15881./1739.		523.6	138.3	25.8	74.8
Whately	206.7	3204./351.		105.6	27.9	5.2	15.1
Totals	19340.4	299775./32818		9882.9	2610.8	487.4	1411.9
% Dairy is of Total Livestock and Poultry Production	81	86	78	78	79	70	73

BOD_5 - 5 day biochemical oxygen demand is a measure of the oxygen used in pounds per year in this table, in water in decomposing organic material by micro-organisms and by chemical reaction of the sample materials. Test is usually run for 5 days for traditional and testing cost considerations.

At a spreading rate of 20 tons/acre, 15,000 acres are needed for disposal of the 19 municipalities' manure total.

TABLE A6-5 - Annual Livestock and Poultry Manure and Pollutant/Nutrient Production for Selected Municipalities

Municipality	Animal Units	Manure Tons / Dry Solids Tons	BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
			1000 pounds			
Ashfield	1849.3	27936./3200.	949.5	250.8	48.5	137.0
Colrain	1194.9	17077./2071.	619.1	166.1	33.0	91.3
Conway	1031.5	14592./1909.	531.4	139.8	29.3	79.3
Greenfield	1097.2	15178./2037.	571.0	150.1	32.0	85.2
Shelburne	1440.8	20738./2547.	738.6	197.3	39.6	110.2
Cummington	1119.8	16938./1926.	567.1	151.3	28.8	83.6
Southwick	1901.1	25911./3362.	1123.9	277.8	71.3	154.2
Westfield	1142.4	17494./1964.	584.6	154.2	29.3	84.0
Agawam	300.6	3999./584.	172.1	42.6	11.2	24.5
Amherst	1174.9	16719./2240.	663.5	170.5	42.5	93.5
Deerfield	2404.8	36099./4179.	1243.3	326.6	64.3	179.1
Easthampton	1238.7	18134./2128.	665.8	171.2	36.3	94.4
Granby	765.0	10988./1398.	418.0	108.5	25.0	60.0
Hadley	2574.9	37848./4304.	1408.5	358.9	77.7	197.4
Hatfield	543.3	7444./997.	288.5	75.2	16.6	42.5
Northampton	541.8	7915./1003.	279.7	72.3	15.2	40.9
Northfield	2095.1	31749./3671.	1071.7	281.9	54.8	155.1
Southampton	1241.9	17967./2331.	635.0	165.2	34.5	94.4
Whately	246.7	3596./459.	126.5	32.9	6.8	18.6
Totals	23904.7	348322./42310.	12657.8	3293.2	696.7	1925.2

BOD_5 - 5-day biochemical oxygen demand is a measure of the oxygen used, in pounds per year in this table, in water in decomposing organic material by micro-organisms and by chemical reaction of the sample materials. Test is usually for 5 days for traditional and testing cost considerations.

The manner in which constituents of manure are transported from areas where manure has been spread or stored depend initially on the degree of solubility of the forms in which these constituents are found. For example, the nitrate form of nitrogen is readily soluble and can be expected to be transported from a site in surface runoff or in any other way water leaves the site such as seepage through the ground. In a surface runoff event, soluble forms of nitrogen would be readily lost, dissolved in the runoff, while relatively non-soluble forms of nitrogen would only leave if solid or particulate matter were carried off. Phosphorus, being relatively non-soluble, mainly leaves with the sediment and other solid material it is attached or associated with. If these solid materials are not transported away, very little phosphorus can be expected to leave. Reducing erosion on a field where manure is spread will have a corresponding and significant reduction in phosphorus loss. Erosion reduction would reduce nitrogen loss on this field but not to the significant degree as with phosphorus.

An estimate of phosphorus increase in water resources is provided in Table A6-6, Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry for Selected Municipalities. Estimates for each community were developed in a similar manner and are based on the same assumptions and so are most useful in comparisons between communities. These values can be added to the average total phosphorus concentration in water resources from cropland erosion values found on Table A6-3 to get an approximate impact on annual phosphorus concentration from agriculture in the water resources on a town-by-town basis.

Information on collection, storage, and disposal of animal manure for 49 dairy operations and 17 other livestock operations in the 19 cities and towns surveyed was gathered. These farms were selected by picking every fourth farm from a listing of all the livestock operations in the 19 cities and towns. Table A6-7 summarizes this information. There are a total of 105 livestock operations in the 49 cities and towns surveyed statewide of which 68 are dairy and 37 are other livestock, which could include beef, swine, horses, ponies, sheep, and goats.

This information forms the basis of our estimates of what practices are necessary to minimize effects on water quality from livestock.

There are nine poultry farms which exceed the minimum criteria for inclusion in this study (at least 10 animal units which is 1,000 turkeys or 2,500 chickens) in the 46 municipalities selected for analysis in this reporting area. There are a few additional flocks which meet this criteria in the 25 towns and cities which were eliminated at the first selection stage from this reporting area because they contained too little agriculture.

Massachusetts Agricultural Water Quality Study

Connecticut River Valley

TABLE A6-6 - Estimated Total Phosphorus Added to Water Resources from Livestock and Poultry Manure for Selected Municipalities.

Municipality	Municipality Total Area Acres	Annual Total Phosphorus Generated 1,000 lbs. 1/	Average Added Total Phosphorus in Water Resources on Yearly Basis 2/ mg/l
Ashfield	25776	48.5	0.007
Colrain	27664	33.0	0.006
Conway	24032	29.3	0.003
Greenfield	14764	32.0	0.005
Shelburne	15460	39.6	0.007
Cummington	14817	28.8	0.007
Southwick	19932	71.3	0.005
Westfield	29858	29.3	0.004
Agawam	15624	11.2	0.001
Amherst	17662	42.5	0.005
Deerfield	21036	64.3	0.010
Easthampton	8701	36.3	0.011
Granby	17925	25.0	0.003
Hadley	16652	77.0	0.012
Hatfield	10598	16.6	0.003
Northampton	22649	15.2	0.002
Northfield	22392	54.8	0.009
Southampton	18912	34.5	0.005
Whately	13012	6.8	0.002
Totals	357466	696.7	---
Average	---	---	0.008

1/ From Table A6-5.

2/ Computations based on annual runoff of 22 inches (1.83 feet), estimated 2% of total phosphorus reaches water resources.

$$\text{Added } P_t \text{ (mg/l)} = \frac{0.02 \text{ Wt } P_t \times 453600 \text{ mg/lb}}{\text{Town Area in Acres} \times 1.83 \text{ ft.} \times 1.234 \times 10^6 \text{ liters/Ac. Ft.}}$$

$$= 0.004 \text{ Wt } P_t/\text{Acres.}$$

Massachusetts Agricultural Water Quality Study

Connecticut River Valley

TABLE A6-7 - Summary of Livestock Operations Manure Handling Survey Data.

Type Operation	Number Range of Livestock	Number of Farms Inventoried	Average Size of Farms Inventoried	Average Number of Dairy Cattle	Average Number of Farm Livestock	Pasture Usage Summer Only	Barn Type: Stanchion	Barn Type: Free Stall or Loose Housing	Manure Storage: Spread Daily	Manure Storage: Use Stacks or Piles	Manure Storage: Adequate Storage Facility	Manure Spreading: On Cropland	Manure Spreading: On Hayland	Manure Spreading: On Pasture	Distribute 25% or More in Winter	Remarks
	Animal Units 1/		Ac.	Animal Units	Animal Units	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	
Small dairy herds	10 to 50	14	140	33	36	13	13	1	4	12	3	10	10	1	2	Barnyard runoff problems noted.
Medium dairy herds	50 to 150	22	170	84	85	21	15	7	6	13	3	21	8	0	10	Runoff problems noted on fields. Barnyard runoff problems noted.
Large dairy herds	Over 150	13	410	282	296	13	4	9	5	9	3	10	6	0	4	Runoff problems noted on fields. Barnyard runoff problems noted.
Other livestock beef, horses, swine	Over 10	17	170	-	51	4	-	17	1	6	8	7	6	2	0	

1/ See Table A3-2 Animal Units.

Our information gathering on actual poultry operations was concentrated in the Chicopee River Reporting Area and in the Central Reporting Area which includes the French, Quinnebaug, Blackstone, Nashua, and Merrimack Rivers in Massachusetts. The major presentation on poultry will be found in the Chicopee River Reporting Area section. A few general comments can be presented here, however, concerning poultry operations. Most poultry farms use housing which allows manure storage under cover from the elements. Poultry manure collection and storage generally present few problems for water quality. The major concern centers on disposal of poultry manure. All the poultry operations surveyed spread manure on agricultural land, either their own or that of neighboring farms. However, over 65 percent of these operations spread during the winter. Spreading manure on snow or frozen ground usually results in excessive runoff of this manure when thaws occur. This results in water quality problems downstream and an economic loss to the farmer in the fertilizer and other values this manure would add to the field where originally spread.

Chapter A7. REPORTING AREA 3 - CHICOPEE RIVER

The Chicopee River basin contains 22 cities and towns. At the first selection stage one city and three towns, Chicopee, East Brookfield, New Salem, and Phillipston, were eliminated because of their small amount of agriculture. See Table A7-1 which is based on 1971 and 1972 land use data. Updated agricultural land use data would probably indicate even lower agricultural acreage in these municipalities. In Table A3-1 county figures for selected towns and cities, which include 92 out of a possible 129 cities and towns in the four counties in which this reporting area lies, range from a 17.8 to a 30.6 percent loss in agricultural land from the 1971-72 survey to 1980.

Eight of the remaining 18 municipalities were selected for detailed analysis. Erosion on agricultural land is the first of these analyses.

Erosion

Sheet and rill erosion estimates were computed for the agricultural land in the eight selected towns in this reporting area. Summaries of these estimates were first presented in Working Paper #3. As Table A7-2 indicates, the expected erosion rates on hayland, pasture, orchards, and nurseries are low. Erosion from these types of agricultural land, which are farmlands with permanently established vegetative cover, contributes little to water quality problems downstream. On the other hand, cropland in the reporting area does have serious erosion problems accompanied by downstream water quality impacts. Table A7-3 presents erosion and associated total phosphorus estimates from cropland for the eight selected towns. The average annual erosion rates on cropland for each town range from 4.1 tons per acre in Monson to 12.8 tons per acre in Spencer. All of the eight towns have average erosion rates which exceed three tons per acre per year which is the "T" value for most soils in Massachusetts. "T" value is the maximum tolerable annual soil loss from a soil conservation perspective. Soil losses at these rates will generally show no deposition of soil in low places and no rilling and sheet erosion.

The estimated increase in total phosphorus concentration is calculated using the methodology presented in Working Paper #3. In that paper unacceptable levels of erosion for a given acreage of cropland in a given watershed area were defined as those that raised the yearly average total phosphorus concentration by 0.010 milligrams per liter. Three towns, Belchertown, Monson, and Warren, do not exceed the total phosphorus increase criteria even though they all exceed an average erosion rate of three tons per acre per year. Cropland erosion in these three towns cannot be considered to contribute significantly to downstream water quality problems. However, there is a need for additional erosion control on the cropland in the three towns because the erosion rates are too high from a soil productivity and conservation viewpoint. The remaining five towns exceed both the total phosphorus, water quality, criteria and the soil conservation or "T" value criteria.

Cropland erosion is one agricultural source of pollutants in water resources, other agricultural sources may include animal wastes and agricultural chemicals such as fertilizer and pesticides. Cropland erosion pollutants combined with pollutants from other agricultural sources may add up to unacceptable water quality problems downstream.

TABLE A7-1 - 1971-72 Agricultural, Urban and Forest Land Use Data for the Cities/Towns Eliminated at the First Selection Stage 1/

City/Town	Agricultural Land Ac.	Agricultural Land % of Total Area	Urban Land Ac.	Urban Land % of Total Area	Forest Land Ac.	Forest Land % of Total Area	Total Land and Water Ac.
Chicopee	605	4.0	8693	58.1	3655	24.4	14956
East Brookfield	678	10.2	477	7.2	4571	68.8	6640
New Salem	691	1.8	185	0.5	27029	71.1	38004
Phillipston	610	3.8	413	2.6	13545	84.8	15964

1/ MacConnell, William P. and William Niedzwiedz, Remote Sensing: 20 Years of Change in Worcester County, Massachusetts, 1951 to 1971, Massachusetts Agricultural Experiment Station, Univ. of Mass., Amherst, 1974, and other similar reports covering Franklin, Hampshire, and Hampden Counties.

Chicopee River Reporting Area

TABLE A7-2 - Summary of Erosion Estimates for Hayland, Pasture, Orchards, and Nurseries for the Eight Most Agricultural Municipalities

Item	Units	Quantity
Hayland - Area	Acres	5101
Annual Erosion	Tons	2463
Annual Average Erosion Rate	Tons/Ac.	0.5
Pasture - Area	Ac.	8817
Annual Erosion	Tons	5055
Annual Average Erosion Rate	Tons/Ac.	0.6
Orchards and Nurseries - Area	Ac.	835
Annual Erosion	Tons	410
Annual Average Erosion Rate	Tons/Ac.	0.5
Total - Area	Ac.	14753
Annual Erosion	Tons	7928
Annual Average Erosion Rate	Tons/Ac.	0.5

Massachusetts Agricultural Water Quality Study

Chicopee River

TABLE A7-3 - Estimated Annual Erosion and Associated Total Phosphorus from Cropland

Basin	Town	Cropland Ac.	Erosion Tons	Erosion Rate Tons/Ac.	Ave. Total Phosphorus Conc. in Runoff from Cropland Erosion 1/ mg P_t/l	Ave. Total Phosphorus Conc. in Water Resources from Cropland Erosion 2/ mg P_t/l
Chicopee	Barre	1040	7831	7.5	0.27	0.010
	Belchertown	813	3523	4.3	0.15	0.003
	Hardwick	921	7590	8.2	0.31	0.010
	Monson	561	2328	4.1	0.15	0.003
	New Braintree	1176	10602	9.0	0.41	0.035
	No. Brookfield	812	6515	8.0	0.35	0.020
	Spencer	835	10687	12.8	0.50	0.019
	Warren	511	3647	7.1	0.30	0.009

1/ This term designated J in Working Paper #3. Values here assume 1.5 lbs. of total phosphorus per ton of sediment and average annual runoff of 22 inches.

2/ This term is J x acres of cropland/total watershed area in acres, and can be added to P_t conc. on an annual basis from other sources.

Animal Waste

The animal numbers presented earlier were used to estimate manure and certain pollutant or nutrient quantities produced by livestock and poultry in the selected towns. Values for specific livestock or poultry from Table 4-1, Daily Production and Composition of Livestock Manure, Agricultural Waste Management Field Manual, an SCS publication, were used. These estimates are presented for dairy cattle and for total livestock and poultry in Tables A7-4 and A7-5.

The number of dairy animals in the eight towns surveyed is approximately 7800 animal units or approximately 67 percent of the total dairy animal units in the 18 towns selected earlier for the reporting area; while the number of total livestock and poultry in the eight towns analyzed, approximately 11,000 animal units, is about 66 percent of the 18 town total. Only poultry operations with more than 10 animal units, equal to 2500 chickens or 1000 turkeys, were included in the survey.

As Tables A7-4 and A7-5 show, substantial amounts of manure are generated in the area. The conventional method of disposal of this material is land spreading. To minimize adverse downstream water quality problems and to maximize benefits to the soil requires consideration of application methods, the livestock or poultry involved, and land, crop and climate factors. 1/

The manner in which constituents of manure are transported from areas where manure has been spread or stored depend initially on the degree of solubility of the forms in which these constituents are found. For example, the nitrate form of nitrogen is readily soluble and can be expected to be transported from a site in surface runoff or in any other way water leaves the site such as seepage through the ground. In a surface runoff event, soluble forms of nitrogen would be readily lost, dissolved in the runoff, while relatively non-soluble forms of nitrogen would only leave if solid or particulate matter were carried off. Phosphorus, being relatively non-soluble, mainly leaves with the sediment and other solid material it is attached or associated with. If these solid materials are not transported away, very little phosphorus can be expected to leave. Reducing erosion on a field where manure is spread will have a corresponding and significant reduction in phosphorus loss. Erosion reduction would reduce nitrogen loss on this field but not to the significant degree as with phosphorus.

1/ Gilbertson, C.B. et al., Animal Waste Utilization on Cropland and Pasture Land, A Manual for Evaluating Agronomic and Environmental Effects. USDA Utilization Research Report 1806, EPA-600/2-79-059, USDA-SEA EPA-ORD, Washington, D.C., Oct. 1979.

TABLE A7-5 - Annual Livestock and Poultry Manure and Pollutant/Nutrient Production for Selected Towns

Town	Animal Units	Manure		Pollutant/Nutrient			
		Tons	Dry Solids Tons	BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
				1000 pounds			
Barre	1200.6	17147.	2093.	657.2	166.9	37.2	92.9
Belchertown	1077.1	14113.	2192.	620.8	160.4	43.4	89.8
Hardwick	2113.5	32096.	3619.	1083.9	286.8	54.7	156.2
Monson	887.4	13840.	1859.	509.9	133.0	28.7	76.3
New Braintree	1751.2	23086.	3248.	1194.3	303.7	92.5	153.1
No. Brookfield	1721.6	22237.	3540.	1339.7	345.0	121.1	162.7
Spencer	1032.2	15288.	1841.	528.8	139.3	27.7	77.4
Warren	1100.4	15816.	2039.	669.0	173.6	46.1	89.3
Totals	10984.0	153623.	20431.	6603.6	1708.7	451.4	897.7

An estimate of phosphorus increase in water resources is provided in Table A7-6, Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry for Selected Municipalities. Estimates for each community were developed in a similar manner and are based on the same assumptions and so are most useful in comparisons between communities. These values can be added to the average total phosphorus concentration in water resources from cropland erosion values found in Table A7-3 to get an approximate impact on yearly phosphorus concentration from agriculture in the water resources on a town-by-town basis.

Information on collection, storage, and disposal of animal manure for 20 dairy operations and nine other livestock operations in the eight towns surveyed was gathered. These farms were selected by picking every fourth farm from a listing of all the livestock operations in the eight towns. Table A7-7 summarizes this information. There are a total of 105 livestock operations in the 49 towns and cities surveys statewide of which 68 are dairy and 37 are other livestock, which could include beef, swine, horses, ponies, sheep, and goats.

This information forms the basis of our estimates of what practices are necessary to minimize effects on water quality from livestock.

Of the 19 poultry operations surveyed, 17 are from Worcester County and further, eight of these operations are in the Chicopee River reporting area. Five turkey farms were sampled while the remaining 14 operations are chicken farms.

The average size of the surveyed turkey farms is 11,000 birds with a size range of 2,000 to 40,000 birds. In Chapter 3, livestock and poultry animal unit numbers are presented for 177 municipalities. In these 177 municipalities there are a total of 14 turkey flocks which are greater than the study minimum of 1,000 turkeys. The average size of these 14 flocks is 7,700 birds.

The average size of the surveyed chicken operations is 54,000 birds while the size range is 5,000 to 200,000 birds. The average size for chicken flocks, all above the study minimum of 2,500 chickens, is 28,000 birds for the 36 flocks counted.

Three of the five turkey operations include a range along with their other housing. These ranges are fenced in areas within which the turkeys roam freely. Manure is usually not collected in these ranges and therefore ranges often have manure runoff problems. The remaining 16 poultry operations are in housing in which the manure is collected.

These 16 operations all have manure storage under cover and have storage capacities for two months' accumulation of manure or more. Of these, eight operations have three to four months' storage and six have six months' or more storage. About half of these operations spread their manure on their own agricultural lands. The other operations furnish their manure to nearby farms for spreading on their agricultural land. Manure from 13 operations is spread in the winter.

In general there is little opportunity for barnyard runoff problems to occur with the notable exception of turkey operations which include a range area. As manure in these ranges is usually not collected, the opportunity for runoff into nearby streams is great.

TABLE A7-6 - Estimated Total Phosphorus Added to Water Resources from Livestock and Poultry Manure for Selected Municipalities

Municipality	Municipality Total Area Acres	Annual Total Phosphorus Generated 1,000 lbs. 1/	Average Added Total Phosphorus in Water Resources on Yearly Basis 2/ mg/1
Barre	28976	37.2	0.005
Belchertown	35468	43.4	0.005
Hardwick	27146	54.7	0.008
Monson	28964	28.7	0.004
New Braintree	13523	92.5	0.027
No. Brookfield	14116	121.1	0.034
Spencer	21844	27.7	0.005
Warren	17628	46.1	0.010
Totals	187665	451.4	---
Average	--	--	0.010

1/ From Table A7-5.

2/ Computation based on annual runoff of 22 inches (1.83 feet), estimated 2% of total phosphorus reaches water resources.

$$\text{Added } P_t \text{ (mg/1)} = \frac{0.02 \text{ Wt } P_t \times 453600 \text{ mg/1b}}{\text{Town Area in Acres} \times 1.83 \text{ ft.} \times 1.234 \times 10^6 \text{ liters/Ac. Ft.}}$$

$$= 0.004 \text{ Wt } P_t\text{/Acres.}$$

Massachusetts Agricultural Water Quality Study

Chicopee River

TABLE A7-7 - Summary of Livestock Operations Manure Handling Survey Data.

Type Operation	Number Range of Livestock	Number of Farms Inventoried	Average Size of Farms Inventoried	Average Number of Dairy Cattle	Average Number of Farm Livestock	Pasture Usage Summer Only	Barn Type: Stanchion	Barn Type: Free Stall or Loose Housing	Manure Storage: Spread Daily	Manure Storage: Use Stacks or Piles	Manure Storage: Adequate Storage Facility	Manure Spreading: On Cropland	Manure Spreading: On Hayland	Manure Spreading: On Pasture	Distribute 25% or More in Winter	Remarks
	Animal Units 1/		Ac.	Animal Units	Animal Units	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	
Small dairy herds	10 to 50	6	80	37	38	6	5	1	1	5	0	4	4	3	6	Runoff problems noted on fields, barnyard runoff problems noted
Medium dairy herds	50 to 150	10	200	85	85	13	13	0	10	2	1	12	9	1	11	Runoff problems noted on fields, barnyard runoff problems noted, inadequate milkouse disposal noted.
Large dairy herds	Over 150	4	350	222	223	4	2	2	4	0	0	4	3	0	4	Runoff problems noted on fields, barnyard runoff problems noted, inadequate milkhouse disposal noted.
Other livestock mostly beef	Over 10	9	160	-	47	6	-	6	0	4	1	3	6	3	2	Runoff problems noted on fields, stacks on steep slopes, barnyard runoff problems.

1/ See Table A3-2, Animal Units

Disposal of poultry manure presents the greatest possibility of adverse impact on water quality. Spreading manure on snow or frozen ground often results in excessive runoff of this manure when thaws occur. At the same time the nutrient value of poultry manure seems too high not to minimize loss of this valuable material.

Improvement in manure disposal methods will include eliminating of manure spreading on farm fields during the more adverse periods of the year. Increases in storage capability and changes in storage operations may be needed to allow proper manure disposal.

Chapter A8. REPORTING AREA 4 - CENTRAL REGION

The Central Region reporting area consists of the following river basins: French and Quinebaug Rivers, Nashua River, Blackstone River, and Merrimack River.

This is essentially the same area covered by the Central Region of the Massachusetts Water Resources Study exclusive of the Assabet, Concord and Sudbury, and Shawsheen Rivers basins. These latter basins which are all tributary to the Merrimack River, contain too little agriculture and were dropped from further analysis earlier in this study.

The Central Region reporting area contains 58 cities and towns. At the first selection stage 21 cities and towns were eliminated from further consideration because of the small amount of agriculture they contain. Table A8-1 lists these municipalities and presents their 1971 agricultural, forest, and urban land acreages. Agricultural land use in 1980 was not obtained for these 21 cities and towns but the statewide loss of agricultural land, for 177 towns and cities surveyed was 27 percent. Updated agricultural land use data would probably indicate even lower agricultural acreage in these 21 municipalities.

Nine of the remaining 37 municipalities were selected for detailed analysis. Erosion on agricultural land is the first of these analyses.

Erosion

Sheet and rill erosion estimates were computed for the agricultural land in the nine selected towns in this reporting area. Summaries of these estimates were first presented in Working Paper #3. As Table A8-2 indicates, the expected erosion rates on hay land, pasture, orchards and nurseries are low. Erosion from these types of agricultural land contribute little to water quality problems downstream.

Table A8-3 presents erosion and associated total phosphorus estimates from cropland for the selected towns. The average annual erosion rate on cropland in the selected municipalities range from 4.3 tons per acre in Brimfield to 15.2 tons per acre in Southbridge. All of these cities and towns have average cropland erosion rates which exceed three tons per acre per year which is the "T" value for most soils in Massachusetts. "T" value is the maximum tolerable annual soil loss from a soil conservation perspective and is the maximum annual erosion rate that can occur without affecting crop productivity over a sustained period.

The estimated increase in total phosphorus concentration is calculated using the methodology presented in Working Paper #3. In that paper unacceptable levels of erosion from a water quality perspective, for a given acreage of cropland in a given watershed area, were defined as those that raised the average annual total phosphorus concentration by 0.010 milligrams per liter. Only four towns equal or exceed the total phosphorus criteria and only those towns are considered to have cropland erosion that contributes significantly to downstream water quality problems.

TABLE A8-1 - 1971 Agricultural, Urban and Forest Land Use Data for the Cities/Towns Eliminated at the First Selection Stage 1/

Basin	City/Town	Agricultural Land Ac.	Agricultural Land % of Total Area	Urban Land Ac.	Urban Land % of Total Area	Forest Land Ac.	Forest Land % of Total Area	Total Land and Water Ac.
French & Quinebaug	Holland	756	9.4	555	6.9	6614	82.1	8056
	Wales	335	3.4	296	3.0	8682	88.8	9774
	Webster	259	2.8	2471	26.6	4640	49.9	9294
Nashua	Ayer	241	4.0	1529	25.4	3225	53.5	6024
	Boylston	457	3.7	813	6.5	8251	66.4	12425
	Clinton	102	2.2	1391	30.1	1751	37.9	4620
	Shirley	867	9.0	867	9.0	7205	74.9	9624
Blackstone	Auburn	952	9.1	3668	35.1	4650	44.5	10447
	Blackstone	907	12.7	1258	17.6	4130	57.7	7156
	Hopedale	29	0.9	962	28.7	2101	62.7	3352
	Millbury	906	8.9	2415	23.6	5463	53.4	10228
	Millville	127	4.0	467	14.7	2209	69.6	3176
	Upton	796	5.8	1248	9.0	10841	78.4	13823
	Worcester	365	1.5	15264	62.3	6964	28.4	24514
Merrimack	Groveland	398	6.5	1304	21.4	3463	57.0	6080
	Lawrence	50	1.1	3941	83.7	324	6.9	4708
	Lowell	115	1.2	6073	65.8	1701	18.4	9232
	Merrimac	798	14.1	935	16.5	3317	58.5	5672
	Newburyport	801	12.1	1990	30.1	1207	18.2	6616
	Salisbury	778	7.1	1506	13.7	4271	38.7	11032
	Tyngsborough	679	6.1	1282	11.4	7753	69.1	11220

1/ MacConnell, William P. and William Niedzwiedz, Remote Sensing 20 Years of Change in Worcester County, Massachusetts, 1951 to 1971, Mass. Agricultural Experiment Station, Univ. of Mass., Amherst, MA 1974 and three other similar reports covering Hampden, Middlesex, and Essex Counties.

Central Region Reporting Area

TABLE A8-2 - Summary of Erosion Estimates for Hayland, Pasture, Orchards, and Nurseries for the Nine Most Agricultural Municipalities

Item	Units	Quantity
Hayland - Area	Acres	5476
Annual Erosion	Tons	2633
Annual Average Erosion Rate	Tons/Ac.	0.5
Pasture - Area	Ac.	4761
Annual Erosion	Tons	2903
Annual Average Erosion Rate	Tons/Ac.	0.6
Orchards and Nurseries - Area	Ac.	1275
Annual Erosion	Tons	630
Annual Average Erosion Rate	Tons/Ac.	0.5
Total - Area	Ac.	11512
Annual Erosion	Tons	6166
Annual Average Erosion Rate	Tons/Ac.	0.5

Massachusetts Agricultural Water Quality Study

Central Reporting Area

TABLE A8-3 - Estimated Annual Erosion and Associated Total Phosphorus from Cropland

Basin	Municipality	Cropland Ac.	Erosion Tons	Erosion Rate Tons/Ac.	Ave. Total Phosphorus Conc. in Runoff from Cropland Erosion 1/ mg P_t/1	Ave. Total Phosphorus Conc. in Water Resources from Cropland Erosion 2/ mg P_t/1
French & Quinebaug	Brimfield	396	1690	4.3	0.17	0.003
	Charlton	829	7964	9.6	0.35	0.010
	Dudley	1131	9819	8.7	0.38	0.031
	Oxford	519	3714	7.2	0.30	0.009
	Southbridge	220	3341	15.2	0.69	0.011
Nashua	Sterling	613	2934	4.8	0.20	0.006
Blackstone	Sutton	930	4145	4.5	0.18	0.007
	Uxbridge	920	6634	7.2	0.29	0.014
Merrimac	Haverhill	472	2734	5.8	0.23	0.005

1/ This term designated J in Working Paper #3. Values here assume 1.5 lbs. of total phosphorus per ton of sediment and average annual runoff of 22 inches.

2/ This term is J x acres of cropland/total watershed area in acres, and can be added to P_t conc. on an annual basis from other sources.

Cropland erosion is one agricultural source of water resource pollution; other agricultural sources may include animal wastes and agricultural chemicals such as fertilizer and pesticides. Cropland erosion pollutants combined with pollutants from these other agricultural sources may add up to unacceptable water quality problems downstream.

Animal Waste

The animal numbers presented earlier were used to estimate manure and certain pollutant or nutrient quantities produced by livestock and poultry in the selected towns. Values for specific livestock or poultry from Table 4-1, Daily Production and Composition of Livestock Manure, Agricultural Waste Management Field Manual, an SCS publication, were used. These estimates are presented for dairy cattle and for total livestock and poultry in Tables A8-4 and A8-5.

The number of dairy animals in the nine cities and towns surveyed is approximately 6,000 animal units or approximately 46 percent of the total dairy animal units in the 37 cities and towns selected earlier for the reporting area; while the number of total livestock and poultry in the nine cities and towns analyzed, approximately 9,800 animal units, is about 41 percent of the 37 city and town total. Only poultry operations with more than 10 animal units, which is 2,500 chickens or 1,000 turkeys, were included in the survey.

As Tables A8-4 and A8-5 show, substantial amounts of manure are generated in the area. The conventional method of disposal of this material is land spreading. To minimize adverse downstream water quality problems and to maximize benefits to the soil requires consideration of application methods, the livestock or poultry involved, and land, crop and climate factors. 1/

The manner in which constituents of manure are transported from areas where manure has been spread or stored depend initially on the degree of solubility of the forms in which these constituents are found. For example, the nitrate form of nitrogen is readily soluble and can be expected to be transported from a site in surface runoff or in any other way water leaves the site such as seepage through the ground. In a surface runoff event, soluble forms of nitrogen would be readily lost, dissolved in the runoff, while relatively non-soluble forms of nitrogen would only leave if solid or particulate matter were carried off. Phosphorus, being relatively non-soluble, mainly leaves with the sediment and other solid material it is attached or associated with. If these solid materials are not transported away, very little phosphorus can be expected to leave. Reducing erosion on a field where manure is spread will have a corresponding and significant reduction in phosphorus loss. Erosion reduction would reduce nitrogen loss on this field but not to the significant degree as with phosphorus.

1/ Gilbertson, C.B. et al., Animal Waste Utilization on Cropland and Pasture Land, A Manual for Evaluating Agronomic and Environmental Effects. USDA Utilization Research Report 1806, EPA-600/2-79-059, USDA-SEA EPA-ORD, Washington, D.C., Oct. 1979.

TABLE A8-4 - Annual Dairy Manure and Pollutant/Nutrient Production for Selected Municipalities

Municipality	Animal Units	Manure		Pollutant/Nutrient			
		Tons	Dry Solids Tons	BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
				1000 pounds			
Brimfield	749.6	11619.	1272.	383.0	101.2	18.9	54.7
Charlton	984.2	15255.	1670.	502.9	132.9	24.8	71.8
Dudley	1031.2	15984.	1750.	526.9	139.2	26.0	75.3
Oxford	279.2	4328.	474.	142.7	37.7	7.0	20.4
Southbridge	159.3	2469.	270.	81.4	21.5	4.0	11.6
Sterling	875.9	13576.	1486.	447.6	118.2	22.1	63.9
Sutton	497.5	7711.	844.	254.2	67.2	12.5	36.3
Uxbridge	805.3	12482.	1367.	411.5	108.7	20.3	58.8
Haverhill	665.2	10311.	1129.	339.9	89.8	16.8	48.6
Totals	6047.4	93735	10262	3090.1	816.4	152.4	441.4
Dairy as a % of Total Livestock and Poultry	62	69	59	52	56	40	55

BOD_5 - 5 day biochemical oxygen demand is a measure of the oxygen used in pounds per year in this table, in water in decomposing organic material by micro-organisms and by chemical reaction of the sample materials. Test is usually run for 5 days for traditional and testing cost considerations.

At a typical spreading rate of 20 tons/acre, 4700 acres are needed for disposal of the nine municipality total.

Massachusetts Agricultural Water Quality Study

Central Region

TABLE A8-5 - Annual Livestock and Poultry Manure and Pollutant/Nutrient Production for Selected Municipalities

Municipality	Animal Units	Manure		Pollutant/Nutrient			
		Tons	Dry Solids Tons	BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
				1000 pounds			
Brimfield	913.6	13290.	1667.	471.9	123.1	25.5	69.2
Charlton	1091.5	16362.	1928.	564.0	147.1	29.4	81.4
Dudley	1150.7	17221.	1987.	593.0	156.5	30.7	86.3
Oxford	1109.9	14480.	1695.	795.8	170.4	54.9	95.4
Southbridge	629.2	7008.	1467.	648.3	165.0	70.4	71.0
Sterling	2067.5	27663.	3369.	1342.3	303.7	88.0	170.9
Sutton	985.8	13006.	1813.	538.3	138.3	32.3	79.3
Uxbridge	932	13791.	1662.	479.9	125.8	25.1	69.9
Haverhill	926.8	12856.	1859.	480.1	121.7	28.0	72.1
Totals	9807.0	135677	17447.	5913.6	1451.6	384.3	795.5

An estimate of phosphorus increase in water resources is provided in Table A8-6, Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry for Selected Municipalities. Estimates for each community were developed in a similar manner and are based on the same assumptions and so are most useful in comparisons between communities. These values can be added to the average total phosphorus concentration in water resources from cropland erosion values found in Table A8-3 to get an approximate impact on annual phosphorus concentration from agriculture in the water resources on a town-by-town basis.

Information on collection, storage, and disposal of animal manure for 15 dairy operations and seven other livestock operations in the nine towns surveyed was gathered. The seven other livestock operations were all small beef or swine operations. These farms were selected by picking every fourth farm from a listing of all the livestock operations in the nine cities and towns. Table A8-7 summarizes this information. There are a total of 105 livestock operations in the 49 cities and towns surveyed statewide of which 68 are dairy and 37 are other livestock, which could include beef, swine, horses, ponies, sheep, and goats.

This information forms the basis of our estimates of what practices are necessary to minimize effects on water quality from livestock.

There are four poultry farms which exceed the minimum criteria for inclusion in this study (at least 10 animal units which is 1,000 turkeys or 2,500 chickens), in the 37 municipalities selected for analysis in this reporting area.

Our information gathering on actual poultry operations was concentrated in the Chicopee River Reporting Area and in the Central Reporting Area which includes the French, Quinebaug, Blackstone, Nashua, and Merrimack Rivers in Massachusetts. The major presentation on poultry will be found in the Chicopee River Reporting Area section. A few general comments can be presented here, however, concerning poultry operations. Most poultry farms use housing which allows manure storage under cover from the elements. Poultry manure collection and storage generally present few problems for water quality. The major concern centers on disposal of poultry manure. All the poultry operations surveyed spread manure on agricultural land, either their own or that of neighboring farms, over 65 percent of these operations spread during the winter. Spreading manure on snow or frozen ground usually results in excessive runoff of this manure when thaws occur. This results in water quality problems downstream and an economic loss to the farmer in the fertilizer and other values this manure would add to the field where originally spread.

TABLE A8-6 - Estimated Total Phosphorus Added to Water Resources from Livestock and Poultry Manure for Selected Municipalities.

Municipality	Municipality Total Area Acres	Annual Total Phosphorus Generated 1,000 lbs. 1/	Average Added Total Phosphorus in Water Resources on Yearly Basis 2/ mg/l
Brimfield	22716	25.5	0.004
Charlton	27901	29.4	0.004
Dudley	13964	30.7	0.009
Oxford	17480	54.9	0.013
Southbridge	13193	70.4	0.021
Sterling	20176	88.0	0.017
Sutton	22032	32.3	0.006
Uxbridge	19145	25.1	0.005
Haverhill	23012	28.0	0.005
Totals	179619	304.3	-
Average	-	-	0.009

1/ From Table A8-5.

2/ Computation based on annual runoff of 22 inches (1.83 feet), estimated 2% of total phosphorus reaches water resources.

$$\text{Added } P_t \text{ (mg/l)} = \frac{0.02 \text{ Wt } P_t \times 453600 \text{ mg/lb}}{\text{Town Area in Acres} \times 1.83 \text{ ft.} \times 1.234 \times 10^6 \text{ liters/Ac. Ft.}}$$

$$= 0.004 \text{ Wt } P_t/\text{Acres.}$$

Massachusetts Agricultural Water Quality Study

Central Region

TABLE A8-7 - Summary of Livestock Operations Manure Handling Survey Data.

Type Operation	Number Range of Livestock	Number of Farms Inventoried	Average Size of Farms Inventoried	Average Number of Dairy Cattle	Average Number of Farm Livestock	Pasture Usage Summer Only	Barn Type		Manure Storage			Manure Spreading			Distribute 25% or More in Winter	Remarks
							Stanchion	Free Stall or Loose Housing	Spread Daily	Use Stacks or Piles	Adequate Storage Facility	On Cropland	On Hayland	On Pasture		
	Animal Units 1/		Ac.	Animal Units	Animal Units	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	
Small dairy herds	10 to 50	2	80	25	30	2	2	0	0	2	0	1	2	0	0	Runoff problem on fields.
Medium dairy herds	50 to 150	9	150	88	91	9	8	1	7	1	2	8	8	1	8	Runoff problms noted on fields, barnyard runoff problems noted.
Large dairy herds	Over 150	4	260	193	193	4	1	3	1	3	0	4	2	0	2	Runoff problems noted on fields, barnyard runoff problems noted.
Other livestock beef and swine	Over 10	7	200	-	20	4	-	7	0	1	2	3	2	1	2	

1/ See Table A3-2, Animal Units

Chapter A9. REPORTING AREA 5 - SOUTHEASTERN REGION

The Southeastern Region reporting area consists of the Buzzards Bay and Mt. Hope Bay and the Taunton River basins. At the first selection stage 12 cities and towns were eliminated because of their small amount of agriculture. See Table A9-1 for agricultural, urban, and forest land use figured for these municipalities. Updated agricultural land use data would probably indicate even lower agricultural acreage as was the case for 177 cities and towns in Massachusetts which had a 27 percent loss in agricultural land from 1971-1972 to 1980. Six of the remaining 23 municipalities were selected for detailed analysis. Erosion on agricultural land is the first of these analyses.

Erosion

Sheet and rill erosion estimates were computed for the agricultural land in the six selected towns in this reporting area. As Table A9-2 indicates the expected erosion rates on hayland, pasture, orchards and nurseries are low. Cranberry bogs it should be noted have essentially little or no soil erosion. Erosion from these types of agricultural land contributes little to water quality problems downstream.

Table A9-3 presents erosion and associated total phosphorus estimates from cropland for the selected towns. Only two of six towns have annual average erosion rates greater than three tons per acre which is the "T" value for most soils in Massachusetts. "T" value is the maximum annual erosion rate that can occur without affecting crop productivity over a sustained period or the maximum tolerable annual soil loss from a soil conservation viewpoint. The annual average erosion rate on cropland for the six towns ranges from 2.0 to 3.7 tons per acre.

The estimated increase in total phosphorus concentration is calculated using the methodology presented in Working Paper #3. In that paper unacceptable levels of erosion from a water quality perspective, for a given acreage of cropland in a given sized watershed, were defined as those that raised the annual average total phosphorus concentration by 0.010 milligrams per liter. Only one town equaled this total phosphorus criteria and no towns exceeded this criteria.

Agricultural sources of water resource pollution include animal wastes and agricultural chemicals as well as cropland erosion. These various sources in combination may add up to unacceptable water quality problems downstream.

Animal Waste

The animal numbers presented earlier were used to estimate manure and certain pollutant or nutrient quantities produced by livestock and poultry in the selected towns. Values for specific livestock or poultry from Table 4-1, Daily Production and Composition of Livestock Manure, Agricultural Waste Management Field Manual, an SCS publication, were used. These estimates are presented for dairy cattle and for total livestock and poultry in Tables A9-4 and A9-5.

TABLE A9-1 - 1971 Agricultural, Urban and Forest Land Use Data for the Cities/Towns Eliminated at the First Selection Stage 1/

Basin	City/Town	Agricultural Land Ac.	Agricultural Land % of Total Area	Urban Land Ac.	Urban Land % of Total Area	Forest Land Ac.	Forest Land % of Total Area	Total Land and Water Ac.
Buzzards Bay	Marion	347	3.8	1455	16.0	6085	66.8	9105
& Mt. Hope	Mattapoiset	590	5.3	1584	14.2	7870	70.7	11136
Bay	New Bedford	199	1.6	7112	55.7	4034	31.6	12777
	Somerset	722	11.7	2805	45.4	848	13.7	6180
Taunton	Abington	338	5.2	2024	31.1	3533	51.5	6508
	Avon	11	0.4	1054	35.0	1612	53.5	3013
	Brockton	314	2.3	8811	64.5	3329	24.4	13665
	Foxborough	430	3.3	2804	21.5	8091	62.1	13032
	Hanson	797	8.0	2089	21.0	5556	55.7	9971
	Mansfield	838	6.5	2405	18.6	8698	67.2	12938
	Plympton	885	9.2	860	8.9	6997	72.6	9632
	Whitman	225	5.1	1665	37.7	1846	41.8	4412

1/ MacConnell, William P., Remote Sensing 20 Years of Change in Plymouth County, Massachusetts, 1951-1971, Cooperative Extension Service, University of Massachusetts, Amherst, MA, 1973, and similar reports for all counties in MA.

TABLE A9-2 - Summary of Erosion Estimates for Hayland, Pasture, Orchards, Nurseries, and Cranberry Bogs for the Six Most Agricultural Towns

Item	Units	Quantity
Hayland - Area	Acres	1573
Annual Erosion	Tons	323
Annual Average Erosion Rate	Tons/Ac.	0.2
Pasture - Area	Ac.	5046
Annual Erosion	Tons	1340
Annual Average Erosion Rate	Tons/Ac.	0.3
Orchards and Nurseries - Area	Ac.	147
Annual Erosion	Tons	32
Annual Average Erosion Rate	Tons/Ac.	0.2
Cranberry Bogs - Area	Acres	3831
Annual Erosion	Tons	0
Annual Average Erosion Rate	Tons/Ac.	0
Totals - Area	Acres	10,597
Annual Erosion	Tons	1,695
Annual Average Erosion Rate	Tons/Ac.	0.2

Massachusetts Agricultural Water Quality Study

Southeastern Region

TABLE A9-3 - Estimated Annual Erosion and Associated Total Phosphorus from Cropland

Basin	Municipality	Cropland Ac.	Erosion Tons	Erosion Rate Tons/Ac.	Ave. Total Phosphorus Conc. in Runoff from Cropland Erosion 1/ mg P_t/l	Ave. Total Phosphorus Conc. in Water Resources from Cropland Erosion 2/ mg P_t/l
Buzzards Bay and Mt. Hope Bay	Carver	101	372	3.7	0.13	0.000
	Dartmouth	2091	5359	2.6	0.09	0.004
	Rehoboth	2649	6138	2.3	0.08	0.007
	Westport	3229	11513	3.6	0.12	0.010
Taunton	Bridgewater	1063	3110	2.9	0.12	0.007
	Middleborough	1190	2401	2.0	0.06	0.002

1/ This term designated J in Working Paper #3. Values here assume 1.5 lbs. of total phosphorus per ton of sediment and average annual runoff of 22 inches.

2/ This term is J x acres of cropland/total watershed area in acres, and can be added to P_t conc. on an annual basis from other sources.

TABLE A9-4 - Annual Dairy Manure and Pollutant/Nutrient Production for Selected Towns

Town	Animal Units	Manure: Tons	Manure: Dry Solids Tons	Pollutant/Nutrient: BOD_5	Pollutant/Nutrient: Total Nitrogen	Pollutant/Nutrient: Total Phosphorus	Pollutant/Nutrient: Total Potassium
				1000 pounds			
Carver	11.9	184.	20.	6.1	1.6	0.3	0.9
Dartmouth	1658.8	25711.	2815.	847.6	223.9	41.8	121.1
Rehoboth	944.6	14641.	1603.	482.7	127.5	23.8	69.0
Westport	3070.6	47594.	5211.	1569.	414.5	77.4	224.2
Bridgewater	2317.5	35921.	3933.	1184.2	312.9	58.4	169.2
Middleborough	1395.0	21623.	2367.	712.8	188.3	35.2	101.8
Totals	9398.4	145674	15949.	4802.4	1268.7	236.9	686.2
Dairy as % of Total Livestock and Poultry	67	74	64	61	63	50	62

BOD_5 - 5 day biochemical oxygen demand is a measure of the oxygen used in pounds per year in this table, in water in decomposing organic material by micro-organisms and by chemical reaction of the sample materials. Test is usually run for 5 days for traditional and testing cost considerations.

At a typical spreading rate of 20 tons/acre, 7300 acres are needed for disposal of the 6 town total of manure.

TABLE A9-5 - Annual Livestock and Poultry Manure and Pollutant/Nutrient Production for Selected Towns

Town	Animal Units	Manure: Tons	Manure: Dry Solids Tons	Pollutant/Nutrient (1000 pounds): BOD_5	Total Nitrogen	Total Phosphorus	Total Potassium
Carver	45	482.	112.	22.2	5.6	1.6	4.1
Dartmouth	2680	36738.	4839.	1438.9	372.6	83.3	211.2
Rehoboth	2620.7	33382.	4720.	1546.4	377.3	99.5	217.5
Westport	4465	63170.	7823.	2686.2	676.2	174.1	359.6
Bridgewater	2534.8	38105.	4479.	1301.4	341.3	67.2	188.6
Middleborough	1611.5	23709.	2932.	869.2	227.3	50.6	123.8
Total	13957.0	195586.	24905.	7864.3	2000.3	476.3	1104.8

Other water pollutants originating from animal manure include chemicals such as sodium, manganese and iron, organic materials and living organisms including bacteria such as the fecal coliform group. In the Westport River Rural Clean Water Project in Bristol County, the most serious pollutant problem is bacteria from animal waste and other sources polluting shellfish beds. These other pollutants could be estimated using average values but the usefulness of the resulting numbers is limited. The nitrogen, phosphorus and potassium estimates have more value as they can be used to determine how much of a crop total fertilizer needs can be supplied from animal waste.

The number of dairy animals in the six towns surveyed is approximately 9400 animal units or approximately 77 percent of the total dairy animal units in the 23 cities and towns selected earlier for the reporting area; while the number of total livestock and poultry in the six towns analyzed, approximately 14,000 animal units, is about 67 percent of the 23 city and town total. Only poultry operations with more than 10 animal units, which is 2500 chickens or 1000 turkeys, were included in the survey.

As Tables A9-4 and A9-5 show, substantial amounts of manure are generated in the area. The conventional method of disposal of this material is land spreading. To minimize adverse downstream water quality problems and to maximize benefits to the soil requires consideration of application methods, the livestock or poultry involved, and land, crop and climate factors. 1/

The manner in which constituents of manure are transported from areas where manure has been spread or stored depend initially on the degree of solubility of the forms in which these constituents are found. For example, the nitrate form of nitrogen is readily soluble and can be expected to be transported from a site in surface runoff or in any other way water leaves the site such as seepage through the ground. In a surface runoff event, soluble forms of nitrogen would be readily lost, dissolved in the runoff, while relatively non-soluble forms of nitrogen would only leave if solid or particulate matter were carried off. Phosphorus, being relatively non-soluble, mainly leaves with the sediment and other solid material it is attached or associated with. If these solid materials are not transported away, very little phosphorus can be expected to leave. Reducing erosion on a field where manure is spread will have a corresponding and significant reduction in phosphorus loss. Erosion reduction would reduce nitrogen loss on this field but not to the significant degree as with phosphorus.

An estimate of phosophorus increase in water resources is provided in Table A9-6, Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry for Selected Municipalities. Estimates for each community were developed in a similar manner and are based on the same assumptions and so are most useful in comparisons between communities. These values can be added to the average total phosphorus concentration in water resources from cropland erosion values found in Table A9-3 to get an approximate impact on annual phosphorus concentration from agriculture in the water resources on a town-by-town basis.

1/ Gilbertson, C.B. et al., Animal Waste Utilization on Cropland and Pasture Land, A Manual for Evaluating Agronomic and Environmental Effects. USDA Utilization Research Report 1806, EPA-600/2-79-059, USDA-SEA EPA-ORD, Washington, D.C., Oct. 1979.

Massachusetts Agricultural Water Quality Study

Southeastern Region

TABLE A9-6 - Estimated Added Total Phosphorus to Water Resources from Livestock and Poultry Manure for Selected Municipalities.

Town	Town Total Area Acres	Annual Total Phosphorus Generated 1,000 lbs. 1/	Average Added Total Phosphorus in Water Resources on Yearly Basis 2/ mg/l
Carver	27504	1.6	0.000
Dartmouth	40493	83.3	0.008
Rehoboth	30493	99.5	0.013
Westport	37036	174.1	0.019
Bridgewater	18183	67.2	0.015
Middleborough	46418	50.6	0.004
Totals	200127	476.3	-
Average	-	-	0.010

1/ From Table A9-5.

2/ Computation based on annual runoff of 22 inches (1.83 feet), estimated 2% of total phosphorus reaches water resources.

$$\text{Added } P_t \text{ (mg/l)} = \frac{0.02 \text{ Wt } P_t \times 453600 \text{ mg/lb}}{\text{Town Area in Acres} \times 1.83 \text{ ft.} \times 1.234 \times 10^6 \text{ liters/Ac. Ft.}}$$

$$= 0.004 \text{ Wt } P_t\text{/Acres.}$$

Massachusetts Agricultural Water Quality Study

Southeastern Region

TABLE A9-7 - Summary of Livestock Operations Manure Handling Survey Data

Type Operation	Number Range of Livestock	Number of Farms Inventoried	Average Number of Dairy Cattle	Average Number of Farm Livestock	Pasture Usage Summer Only	Barn Type: Stanchion	Barn Type: Free Stall or Loose Housing	Manure Storage: Spread Daily	Manure Storage: Use Stacks or Piles	Manure Storage: Adequate Storage Facility	Manure Spreading: On Cropland	Manure Spreading: On Hayland	Manure Spreading: On Pasture	Distribute 25% or More in Winter	Remarks
	Animal Units 1/		Animal Units	Animal Units	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	
Small dairy herds	10 to 50	3	34	40	1	2	1	0	0	1	0	1	2	1	
Medium dairy herds	50 to 150	11	90	91	1	8	3	3	6	4	7	1	5	4	Runoff problems noted on fields, barnyard runoff problems noted.
Large dairy herds	Over 150	4	232	248	1	1	3	1	2	1	4	3	1	1	Runoff problems noted on fields, barnyard runoff problems noted.
Other livestock	Over 10	13	-	36	-		12	5	10	1	4	6	3	3	

1/ See Table A3-2, Animal Units

Information on collection, storage, and disposal of animal manure for 18 dairy operations and 13 other livestock operations in the six towns surveyed was gathered. These farms were selected by picking every fourth farm from a listing of all the livestock operations in the six towns. Table A9-7 summarizes this information. There are a total of 105 livestock operations in the 49 cities and towns surveyed statewide of which 68 are dairy and 37 are other livestock, which could include beef, swine, horses, ponies, sheep, and goats.

This information forms the basis of our estimates of what practices are necessary to minimize effects on water quality from livestock.

There are seven poultry farms which exceed the minimum criteria for inclusion in this study (at least 10 animal units which is 1,000 turkeys or 2,500 chickens), in the 23 municipalities selected for analysis in this reporting area.

Our information gathering on actual poultry operations was concentrated in the Chicopee River Reporting Area and in the Central Reporting Area which includes the French, Quinnebaug, Blackstone, Nashua, and Merrimack Rivers in Massachusetts. The major presentation on poultry will be found in the Chicopee River Reporting Area section. A few general comments can be presented here, however, concerning poultry operations. Most poultry farms use housing which allows manure storage under cover from the elements. Poultry manure collection and storage generally present few problems for water quality. The major concern centers on disposal of poultry manure. All the poultry operations surveyed spread manure on agricultural land, either their own or that of neighboring farms. However, over 65 percent of these operations spread during the winter. Spreading manure on snow or frozen ground usually results in excessive runoff of this manure when thaws occur. This results in water quality problems downstream and an economic loss to the farmer in the fertilizer and other values this manure would add to the field where originally spread.

Chapter A10. CONSERVATION PLANNING

The SCS working through conservation districts, which cover the entire state, assists landowners and other land users in planning and applying conservation measures to their land. These measures include practices designed to reduce erosion and sediment and to improve management of agricultural sources of pollution. In addition, conservation measures are planned to meet other objectives such as improving wildlife habitat, soil and plant productivity, and environmental quality.

The SCS has a progress reporting system to keep track of accomplishments which have occurred on the land with SCS technical assistance. This reporting system also plays an important part in planning future activities and goal setting for the SCS.

The items presented in Table A10-1, Conservation Reportable Items and Practices Accomplished During the Five-Year Period (1978-1982) in Massachusetts, were selected because they are important for control of erosion on cropland or for management of agricultural wastes. These 17 items on this table were selected from a list of over 150 items and practices. Although these accomplishment numbers indicate progress there still remains much to do to control on-farm sources of water pollution. This is particularly evident in agricultural waste management. SCS has been assisting cooperators for about 6 years in developing livestock waste management systems. Since agricultural waste management systems are usually costly and complex, little accomplishment has been achieved to date. Another factor is that only complete systems can be reported and sometimes the full installation period may extend over several years. Components may be reported as accomplished but the complete system can be reported only after its completion.

Reasons for the lack of progress include:

1. High cost of many of the components of waste management systems.

2. Lack of knowledge of the off-farm effects of poor manure handling procedures.

3. Until recently the economic value of the fertilizer values in animal manures was not sufficiently realized. Substitutes such as chemical fertilizers were relatively inexpensive until recently.

In order to obtain a more detailed perspective on conservation activities in Massachusetts, four towns were selected for further review of conservation planning. The towns selected, Ashfield, Colrain, Northfield, and Whately, are included in the 49 cities and towns which were originally selected for detailed erosion and livestock manure analysis. A Status of Conservation Efforts Worksheet was developed (see Figure A10-1). This worksheet was used to codify and consolidate information from all the conservation plans on file for each of the sample towns. Results from that analysis are summarized in Table A10-2, Conservation Planning in Four Selected Towns.

Table A10-1 - Conservation Reportable Items and Practices Accomplished During the Five-Year Period (1978-1982) in Massachusetts

Reportable Item or Conservation Practice	Units	Quantity
Conservation District Cooperators	No. & Acres	745/75364
Conservation Plans	Acres	60066
Waste Management System	No.	21
Waste Storage Structure	No.	10
Conservation Cropping System	Acres	2425
Conservation Tillage System	Acres	507
Contour Farming	Acres	207
Cover and Green Manure Crop	Acres	9518
Diversion	Feet	7573
Grade Stabilization Structure	No.	71
Grassed Waterway or Outlet	Acres	29
Waste Storage Pond	No.	6
Lined Waterway or Outlet	Feet	1393
Contour Stripcropping	Acres	287
Field Stripcropping	Acres	141
Waste Utilization	No. & Acres	4/161
Cropland Adequately Protected	Acres	20585

Figure A10-1

AWQS

STATUS OF CONSERVATION EFFORTS WORKSHEET

1. Town ____________________ Plan No. ________ Name ______________________________

Location ________________ Street   Size of Farm __________ acres

________________ grid numbers and field numbers   No. of Animal Units __________ (if applicable)

2. Is this "plan" area shown on the 1980 Agricultural Land Use Survey? Yes   No
If no, Why?

Check below:

(   ) Land developed for urban use.
(   ) Land in forest, abandoned field or other non-agricultural land use.
(   ) Other, specify: ____

____

3. Fill out remainder of sheet only if answer to question 2 is yes.

4. Present agricultural land use -- Practices applied:

Type	Area acres	Land adequately treated	List installed measures
Cropland			
Hayland			
Pasture			
Orchard			
Other agric. land			

5. List measures recommended in plan, which contribute to erosion or water quality problem reduction which have not been installed:

Practices Planned	Acres Affected

6. Other Comments applicable to erosion control, sediment reduction, water quality benefits (pollution abatement):

Table A10-2 - Conservation Planning in Four Selected Towns

Item	Units	Sample Towns: Ashfield	Whately	Northfield	Colrain
1. Number of conservation plans	No.	58	63	34	55
2. Total agricultural land reported in plans 1/	Acres	2753	1846	1537	2217
3. 1980 total agricultural land from Agricultural Water Quality 1/ Study Inventory	Ac.	2987	2780	3433	3454
4. Agricultural land included in conservation plans as a percentage of 1980 total agricultural land	%	92	66	45	64
5. Cropland area in conservation plans	Acres	450	963	606	354
6. Percent cropland listed as adequately treated in conservation plans	%	79	90	93	57
7. Cropland area from 1980 AWQS Inventory	Ac.	344	1662	2223	994
8. Percentage cropland adequately treated from erosion estimates of AWQS	%	22	91	81	18
9. Hayland, Pasture and Orchards area in conservation plans	Acres	2303	883	931	1863
10. Percentage Hayland, Pasture and Orchards considered adequately treated in conservation plans	%	82	82	64	57
11. Hayland, Pasture and Orchards and Nurseries from 1980 AWQS Inventory	Acres	2643	1118	1210	2460

1/ Includes Cropland, Hayland, Pasture, and Orchards and Nurseries only.

As some of the operations for which conservation plans were developed have undergone conversion to some non-agricultural land use, the first question for any operation is whether it is still in agriculture. In the sampled four towns 11 percent of the conservation plans, 23 plans of a total 210 plans, do not include any cropland, hayland, pasture, orchards, or nursery land.

For these operations or locations there are no cropland erosion or livestock problems which could contribute to downstream water quality problems. The agricultural land in conservation plans equals 66 percent of the 1980 agricultural land use of the four towns while the cropland in conservation plans equals 45 percent of the 1980 agricultural land use.

Much of the emphasis in conservation plans is towards erosion reduction on agricultural land which, of course, is and has been a major objective of conservation districts and the SCS. Only in the last four or five years has emphasis in agricultural waste management been evident in these conservation plans.

Chapter A11. FERTILIZER USE IN MASSACHUSETTS AGRICULTURE

Fertilizer used in agriculture is another potential source of pollution of the state's water resources. Earlier, this report presented information on the potential effects on water quality from organic fertilizers such as livestock and poultry manures. In this chapter our analysis will be restricted to chemical fertilizers.

In 1980, over 65,000 tons of fertilizer were used by Massachusetts agriculture.[1/] Labels for fertilizer usually list the pounds of nutrients; nitrogen as N, phosphorus as P_2O_5 commonly called phosphate, and potassium as K_2O, potash; in a 100 pound quantity of fertilizer and in the same order. For example, a 100 pound bag of fertilizer labeled 10-10-10 would contain 10 pounds of N, 10 pounds of P_2O_5, and 10 pounds of K_2O. The remaining 70 pounds would contain some secondary, micro, and trace elements but would mainly consist of inert materials. The 1980 total amount of fertilizer included about 9100 tons of nitrogen as N, 5500 tons of phosphate, P_2O_5, and 6400 tons of potash, K_2O.

Table A11-1 shows harvested cropland and fertilizer consumption statistics for selected years, 1950 to 1980. Dividing nutrient quantities by harvested acreage gives an average nutrient usage per acre of cropland in the state. These average values can be compared with those of Table 11-2, Fertilizer Application Rates in Massachusetts. These are application rates recommended by the Extension Service agronomists and other specialists for farm crops in this state. These fertilizer application rates were used to develop average application rates weighted by percentage of total acres with the same recommended rates. In comparing weighted average recommended application rates, Table A11-2, and average consumption rates, Table A11-1, we find that they are similar. It therefore seems reasonable to use the recommended application rates as our average fertilizer use values.

The cost of fertilizer is of concern to farmers. In 1982, costs for a ton of 10-10-10 ranged from approximately \$185 to \$234. These values result in the following costs per pound: 38 to 48 cents per pound of nitrogen, 32 to 41 cents per pound of phosphate, P_2O_5, and 22 to 28 cents per pound of potash, K_2O. With these high costs for fertilizers, there is a tendency for farmers to apply recommended rates or less. In general we expect few situations of excessive applications of fertilizer because of these cost considerations.

In cranberry country, southern Plymouth County and adjacent areas, water quality impacts from cranberry culture are thought to result primarily from fertilizer, pesticide, and herbicide applications. Using recommended application rates from Table A11-2, estimates were made of possible impacts of cranberry bog fertilization on local water resources. Two cases are presented, a high nutrient runoff condition and a low condition, in Table A11-3. As there is little information available on fertilizer losses from cranberry bogs, these cases are only of value for illustrative purposes. Even with these reservations on this analysis two points can be made: 1) phosphorus concentration increases from bog fertilization may contribute to aquatic plant problems in downstream waters, 2) increases in nitrogen levels are expected to be relatively small.

1/ New England Crop and Reporting Service, Massachusetts Agricultural Statistics, Massachusetts Agriculture 1981, Concord, NH, p. 34

In relatively unpolluted waters in Massachusetts total nitrogen concentrations are usually much greater than total phosphorus concentrations. In the White Island Pond Water Quality Study, 1976-1978, six chemical analyses of an inlet stream, Station 4, were taken in 1976 to 1978. White Island Pond, surface area of 284 acres, is located in the towns of Plymouth and Wareham. Land uses in the pond watershed are forest (57 percent), cranberry production (27 percent), and residential (16 percent). Total nitrogen concentrations for this testing series ranged from 0.26 to 1.0 mg N/l with an average value of 0.55 mg/l. Total phosphorus concentrations ranged from 0.02 to 0.14 mg P/l with an average value of 0.07 mg P/l. 1/

An increase of 0.05 mg/l in the nitrogen concentration at this station would usually be a much smaller relative change than would a 0.05 mg/l increase in the phosphorus concentration. Generally it is expected that the total nitrogen concentration will be five to over 25 times greater or more than the total phosphorus concentration in natural waters. Usually a small change in phosphorus concentration will represent a much greater percent change in phosphorus than would the same numerical change in nitrogen concentration.

A partial explanation for the low nitrogen increases in downstream waters comes from Note B of the Cranberry Fertilizer Chart, issued by the Extension Service:

> "A crop of 100 barrels per acre plus one ton of vegetative material removes 23 lbs. of nitrogen, 10 lbs. of phosphorus and 18 lbs. of potassium from the soil. Applying 230 lbs. 10-20-10 or comparable amounts of other analyses replaces the nitrogen. Much of the phosphorus is unavailable to the plant because of the nature of cranberry soils and the potassium leaches out very rapidly." 2/

The three-year (1978-1980) average yield per acre for the 11,200 acres of productive bogs in Massachusetts was 102 barrels per acre. 3/ A five-year (1976 to 1980) average yield was 95 barrels per acre. The 100 barrel yield mentioned in the note above is, therefore, a typical or expected yield. As shown on Table A11-2, the recommended nitrogen application rate for productive cranberry vines is 20 pounds per acre per year. In general it can be said that the cranberry producer attempts to apply only as much nitrogen as the plants can use on a yearly basis.

1/ Whittaker, Gayle E., White Island Pond Water Quality Study 1976-1978, Water Quality and Research Section, Mass. Division of Water Pollution Control, Westborough, Mass., June 1980, pp. 7, 11, 16, and 38.

2/ Demoranville, I.E., "Cranberry Fertilizer Chart," Extension Service, U.S Department of Agriculture and County Extension Service Cooperating, Revised Jan. 10, 1982.

3/ New England Crop and Livestock Reporting Service, Massachusetts Agricultural Statistics, Massachusetts Agriculture, 1981, Concord, NH, p. 27.

TABLE A11-1 - Cropland and Fertilizer Statistics, 1950 to 1980 1/

Year	Harvested Cropland 2/	Harvested Cropland Veg. & Fruit 3/	Total Harvested Cropland 4/	Statewide Fertilizer Consumption				Average Fertilizer Consumption Per Acre		
				N	P_2O_5	K_2O	P 6/	N	P_2O_5	P
	Ac.	Ac.	Ac.	Tons	Tons	Tons	Tons	Lbs.	Lbs.	Lbs.
1950	400,000	12,960	413,660	4,526	9,817	6,6670	4,280	21.9	47.5	20.7
1955	323,800	10,430	334,230	5,585	8,568	7,055	3,779	32.8	51.3	22.6
1960	277,50	8,600	286,100	6,761	8,117	6,912	3,539	47.3	56.7	24.7
1965	228,500	5,780	234,280	8,425	8,684	7,741	3,786	71.9	74.1	32.3
1970	176,070	3,680	179,750	8,159	6,325	6,071	2,758	90.8	70.4	30.7
1975	182,350	3,430	185,780	7,866	5,586	6,049	2,436	84.7	60.1	26.2
1976	186,930	N.D. 5/	186,930	8,803	5,984	6,779	2,609	94.2	64.0	27.9
1977	187,920	N.D.	187,920	9,015	5,872	6,607	2,560	95.9	62.5	27.2
1978	188,000	N.D.	188,000	11,501	7,644	8,552	3,333	122.4	81.3	35.5
1979	186,110	N.D.	186,110	10,275	6,220	7,530	2,712	110.4	66.8	29.1
1980	187,780	N.D.	187,780	9,092	5,462	6,380	2,381	96.8	58.2	25.4
Six-year average 1975-1980	186,500	-	187,100	9,425	6,128	6,983	2,671	100.7	65.5	28.6

1/ Massachusetts Department of Food and Agriculture and U.S. Department of Agriculture Statistical Reporting Service, Massachusetts Agricultural Statistics, 1981, and earlier similar reports, New England Crop and Livestock Reporting Serivce, Concord, NH.

2/ Includes silage, grain and sweet corn, hay, potatoes, tobacco, cranberries, and tomatoes.

3/ Includes asparagus, snap beans, cabbage, carrots, celery, cucumbers, lettuce, onions, green peppers, spinach, and strawberries. Collection of harvested acreage of these crops was discontinued by 1976.

4/ Addition of columns 1 and 2. Other data sources including the Federal Census of Agriculture indicates slightly higher value for harvested cropland. The 1978 Federal Census figure is about 214,000 acres but these will be used as they result in larger average fertilizer application rates.

5/ N.D. = No data.

6/ P = 0.436 P_2O_5; Phosphorus portion of P_2O_5.

TABLE A11-2 - Fertilizer Application Rates in Massachusetts

Data Source: Fertilizer Rates from 1982 New England Vegetable Production Recommendations published by Cooperative Extension Service, Univ. of Mass., C-154, or from SCS Crop Budget developed by SCS. Cropland Acreage - Mass. Agriculture 1980., Mass Rept. of Food & Agriculture and USDA - E, SCS, compiled by New England Crop & Livestock Reporting Service or 1978 Census of Agriculture.

Crop	1978 Acreage Harvested	Recommended Rates in Lbs./Acre High End of Range 1/ N	P_2O_5	K_2O	P
Vegetables					
Sweet corn	7,241	160	220	220	95.9
Tomatoes	542	230	320	250	139.5
Potatoes	3,504	180	200	200	87.2
Cabbage	816	150	100	100	43.6
Cucumbers	699	100	150	150	65.4
Snap beans	484	40	100	100	43.6
Onions	230	100	150	150	65.4
Pumpkins	627	50	150	150	65.4
Squash	1,923	50	150	150	65.4
Asparagus	269	80	150	225	65.4
Lettuce	344	90	180	180	78.5
Subtotal	16,679				
Weighted Average		139.8	193.1	192.	84.2
		Recommended rates 2/			
Grain and Silage corn	42,358	167	80	80	34.9
Alfalfa hay	27,375	0	60	120	26.2
Other tame hay	80,548	60	60	60	26.2
Wild hay	12,208	60	60	60	26.2
Cranberries	10,063	20	40	20	17.4
Subtotal	189,231				
Weighted Average		80.2	75.1	82.6	32.8

1/ From 1982 New England Vegetable Production Recommendations.

2/ From SCS Crop Budget Analysis.

TABLE A11-3 - Estimated Nutrient Runoff From Cranberry Bogs in Selected Towns

Town	Cranberry Bog Area Ac	Total Town Area Ac	High Runoff Case Nutrient Concentration-Yearly Average: Water from Bogs		High Runoff Case: Increase to Town Water Resources		Low Runoff Case Nutrient Concentration-Yearly Average: Water from Bogs		Low Runoff Case: Increase to Town Water Resources		Town Total Nutrients Applied to Bogs (1000 lbs)		
			mg N/l	mg P/l	mg N/l	mg P/l	mg N/l	mg N/l	mg N/l	mg P/l	N	P_2O_5	P
Carver	2,944	27,504	0.29	0.077	0.086	0.022	0.04	0.019	0.013	0.006	58.9	117.8	51.3
Middle-borough	800	46,418	0.29	0.077	0.014	0.004	0.04	0.019	0.002	0.001	16.0	32.0	14.0
Wareham	1,759	23,745	0.29	0.077	0.059	0.016	0.04	0.019	0.009	0.004	35.2	70.4	30.7
Plymouth	1,136	62,915	0.29	0.077	0.015	0.004	0.04	0.019	0.002	0.001	22.7	45.4	19.8
Rochester	774	23,062	0.29	0.077	0.027	0.007	0.04	0.019	0.004	0.002	15.5	31.0	13.5

1. Used fertilizer application rate of 200 lbs of 10-20-10 per year which equals an annual rate of 20 lbs N, 40 lbs P_2O_5 and 20 lbs K_2O.

2. Two runoff conditions are analyzed: High runoff case with a nitrogen loss of 20 percent and a phosphorus loss of 6 percent and a low runoff case with a nitrogen loss of 3 percent and a phosphorus loss of 1.5 percent.

3. Amount of water applied to bogs estimated at 60 inches per acre yearly. This is water applied for irrigation, frost protection, harvesting and other crop needs. Nutrient concentrations in water from bogs are based on this volume. Additional concentrations in town water resources are based on 22 inches annual runoff. The water applied to the bogs, 60 inches, is supplied from adjacent water resources which average approximately 22 inches of runoff per year.

In areas of the state where cranberries are concentrated, there is little other agriculture. Animal waste and soil erosion problems are minimal and it is thought that the only types of downstream pollution problems originating from agriculture in this area could only come from agricultural chemical application. Of the fertilizer components considered, there is the possibility of excessive phosphorus concentrations downstream but little likelihood of excessive nitrogen concentrations stemming from cranberry bogs downstream. In many lakes in Massachusetts phosphorus is often the nutrient controlling aquatic plant growth.

Statewide, chemical fertilizer application on agricultural land can add to downstream water quality problems. Nitrogen can easily leave the location, where applied, in nitrate and other soluble forms in runoff. Also nitrogen in less soluble forms and associated with soil particles will be moved with soil erosion. The principal mode for loss of applied phosphorus is with soil erosion as phosphorus adsorbs strongly in soil particles. 1/

1/ Stewart, B.A., D.A. Woodhiser, W.H. Wischmeier, J.H. Coro and M.H. Frere, Control of Water Pollution from Cropland, Volume I, A Manual for Guideline Development, Office of Research and Development, EPA and Agricultural Research Service, USDA, EPA-600/2-75-026a and ARS-H-5-1, November 1975.

Chapter A12 - PESTICIDE USE IN MASSACHUSETTS AGRICULTURE

In Massachusetts pesticides have been used for many objectives and on many different land uses. These include such applications as mosquito and other insect control in populated areas, insect control for forest production purposes and applications for insect, weed and disease control in agriculture.

In this chapter, we will concentrate on agricultural uses of pesticides. The 1978 Federal Census of Agriculture states that pesticides are used in Massachusetts to control insects on 42,200 acres of hay and other crops, to control plant diseases on 22,900 acres of crops and orchards, and to control weeds on 59,500 acres of crops and pastures. This census lists the total cropland as 311,030 acres and the harvested cropland as 213,669 acres for Massachusetts [1/].

Pesticides Presently Used

Tables A12-1, A12-2 and A12-3 list those insecticides, herbicides and fungicides approved for use in 1983 in the state.

Pesticides are first approved for use on a national basis by the U.S. Environmental Protection Agency. Regulation and approval of pesticides for use in the state is carried out under the Pesticide Program administered by the Massachusetts Department of Food and Agriculture.

1/ U.S. Department of Commerce, Bureau of the Census, 1978 Census of Agriculture, Volume 1, State and County Data, Part 21, Mass. AC78-A-21, Washington, D.C., March 1981, pp. 1 and 8.

Table A12-1 - A Listing of Insecticides Approved for Use in Massachusetts (1983)

Chemical Type	Common Name/ Trade Name	Predominant Transport Mode1/	Toxicity2/ RAT Acute Oral LD50 mg/kg	FISH3/ LC50 mg/liter	Crops on which Material is Used4/	Solubility of Pure Chemical in Water @ 25°C g/100g	Most Probable Month(s) in Which Material is Applied5/
Carbamates	aldicarb/ Temik	W	0.93		VE	<1	AP, MA, JU
	carbaryl/ Sevin	SW	500	1.0	OR, CB, VE, SF, SC, FC	<1	MR, AP, MA, JU, JL, AU
	carofuran/ Furadan	SW	8	0.21	VE, FC, SC, SF	<1	AP, MA, JU, JL
	methomyl/ Lannate	U	17	0.9	OR, VE, SC	5.8	AP, MA, JU, JL
Cylic Oxygen Compounds	metaldehyde/ Metason	W	1000	>100.0			
Organo Chlorines	dicofol/ Kelthane	S	684	0.10	OR, VE, SF	<1	AP, MA, JU,
	endoulfan/ Thiodan	S	18	0.001	SF, VE	<1	
	methoxychlor/ Marlate	S	5000	0.007	VE, SF	<1	MA, JU, JL
Organo Phosphorous Compounds	azinphos methyl/ Guthion	S	11	0.010	OR, CB, VE, SF	<1	AP, MA, JU, JL, AU
	chlorpyrifos/ Dursban	U	97	0.020	VE, SC, FC		AP, MA
	diazinon/ Basudin	SW	76	0.030	OR, CB, VE, SF	<1	AP, MA, JU, JL, AU
	fonofos/ Dyfonate	S	8	0.03	VE, SC, FC	<1	AP, MA, JU
	malathion	W	480	0.019	CB, VE, SF	<1	AP, MA
Organo Phosphorous Compounds	parathion	S	4	0.047	CB, VE, SF	<1	MA, JU, JL, AU
	phosalone/ Zolone	S	96	3.4	OR, VE, SF	<1	JU, JL, AU
Aromatic and and Cylic Sulfur Compounds	propargite/ Omite	U	2200	0.03	OR, CB		MR, AP, MA, JU, JL, AU

1/ Where movement of insecticides in runoff from treated fields occurs, S denotes those chemicals that will most likely move primarily with the sediment; W denotes those that will most likely move primarily with the water; SW denotes those that will most likely move in appreciable proportion with both soil and water; and U denotes those whose predominant mode of transport cannot be predicted because properties are unknown.

2/ Expressed as the lethal dose, or lethal concentration, to 50 percent of the test animals (LD_{50} or LC_{50}, respectively).

3/ 48- or 96-hour LC_{50} for bluegills or rainbow trout.

4/ Following abbreviations used: FC - Field Corn, SC - Sweet Corn, VE - Vegetables, CB - Cranberries, SF - Small Fruit and OC - Orchards.

5/ MR - March, AP - April, MA - May, JU - June, JL - July, and AU - August.

Table A12-2 - A Listing of Herbicides Approved for Use in Massachusetts (1983)

Chemical Type	Common Name/ Trade Name	Predominant Transport Model[1]	Toxicity[2] RAT Acute Oral LD50 mg/kg	Toxicity[2] FISH[3] LC50 mg/liter	Approximate Persistance in Soil days	Crops on which Material is Used[4]	Solubility of Pure Chemical in Water @ 25°C g/100g	Most Probable Month(s) in Which Material is Applied[5]
Aliphatic Acids	glyphosate/ Round-up	S	4320	Low toxicity	150	NFC, NPA, NHL, FC, SC, PA, HL, OR, CB, SF, VE	1.2	AP, MA, JU, JL, AU, SE
	dalapon/ Dowpon	W	6590	>100	15-30	CB, OR, VE	Completely soluble	AP, MA, JU
Amides and Anilides	alachlor/ Lasso	SW	1200	2.3	40-70	FC, VE, SC	<1	MA, JU
	bensulide Betasan	S	770	0.72	500-700	VE	<1	AP, MA, JU
	diphenamid/ Enide	W	970	25.0	90-180	SF, VE	<1	MA, JU
	metolachlor/ Dual	S	2780	15.0	60-100	FC	<1	MA, JU
	oryzalin/ Surflan	S	>10000	Low toxicity	-	FC, SF	<1	AP, MA, JU
	pronamide/ Kerb	S	5620		60-270	FC, VE	<1	AP, MA, JU
	propachlor/ Ramrod	W	710	1.3	30-50	VE	<1	AP, MA, JU
Aromatic Acids and Esters	DCPA/ Dacthal	S	3000	>500	400	SF, VE	<1	AP, MA
	dicamba/ Banvel	W	1028	35	-	FC, HL, PA	<1	AP, MA, JU, JL, AU, SE
Carbamates and Thio Carbamates	butylate/ Sutan	S	4500	4.2	40-80	FC, SC	<1	AP, MA, JU
	chlorpropham/ Furloe; chloro-IPC	SW	1500	10.0	120-260	CB, FC, HL	<1	MR, AP, MA, OC-FE
	EPTC/Eptam	SW	1360	19.0	30	FC, HL, PA, VE	<1	AP, MA, JU, AU, SE
Cationics	diquat/ Diquat	S	400	12.3	>500	CB	Completely soluble	JU, JL
	paraquat/ Paraquat	S	150	400[6]	7500	NFC, NHL, NPA, HL, SF, OR	Completely soluble	MR, AP, MA, JU, JL, AU, SE
Diazines	terbacil/ Sinbar	W	5000	86[7]	700	HL, SF, OR	<1	FE, MR, JU, JL, AU, SF, OC, NO
Nitriles	dichlobenil/ Casoron	S	3160	10-20	60-180	CB, SF, OR	<1	FE, MR, AP, MA, NO, DE
Phenols and Dicarboxylic Acids	dinoseb/ Premerge	SW	5	0.40[8/9]	15-30	HL, PA, VE, SC	<1	MA, JU
	endothol/ Des-i-cate Aquathol	W	38	1.15		VE	10	AU, SE, OC
Phenoxy Compounds	2,4-D Acid/ Many	W	370	>50[10]	10-30	VE	<1	MA, JU, JL, AU, SE, OC
	2,4-D Ester/ Many	S	500-875	4.5[11]	10-30		<1	MA, JU, JL, AU, SE, OC
Triazines and Triazoles	atrizine/ Aatrex	SW	3080	12.6	300-500	FC, SC	<1	AP, MA, JU
	cyanazine/ Bladex	SW	334	4.9		FC, SC	<1	AP, MA, JU
	metribuzin/ Lexone	W	1930	>100	150-200	HL, VE	<1	AP, MA, JU, NO, DE, JA, FE
	simazine/ Princep	S	5000	5.0	200-400	CB, FC, SC, HL, SF, OR, VE	<1	AP, MA, JU
Ureas	diuron/ Karmex	S	3400	>60	200-500	SF, OR, VE	<1	MR, AP, MA
Inorganics	copper Sulfate	W	470	0.135		CB	Soluble	FE, MR

1/ Where movement of insecticides in runoff from treated fields occurs, S denotes those chemicals that will most likely move primarily with the sediment; W denotes those that will most likely move primarily with the water; SW denotes those that will most likely move in appreciable proportion with both soil and water.

2/ Expressed as the lethal dose, or lethal concentration, to 50 percent of the test animals (LD_{50} or LC_{50}, respectively).

3/ 48- or 96-hour LC_{50} for bluegills or rainbow trout, unless otherwise specified.

4/ Following abbreviations used: FC - Field Corn, NFC - No-till Field Corn, SC - Sweet Corn, PA - Pasture, NPA - No till Pasture, VE - Vegetables, CB - Cranberries - SF - Small Fruits, HL - Hayland, NHL - No-till Hayland, and OR - Orchard.

5/ JA - January, FE - February, MR - March, AP - April, MA - May, JU - June, JL - July, AU - August, SE - September, - OC - October, NO - November, and DE - December

6/ 24-hour LC_{50}

7/ For sunfish

8/ For goldfish

9/ LC_{100}

10/ For spot

11/ For killifish

Table A12-3 - A Listing of Fungicides Approved for Use in Massachusetts (1983)

Common Name/ Trade Name	Predominant Transport Model 1/	Toxicity 2/ RAT Acute Oral LD50 mg/kg	Toxicity 2/ FISH 3/ LC50 mg/liter	Crops on Which Material is Used 4/	Solubility of Pure Chemical in Water @ 25°C g/100g	Most Probable Month(s) in Which Material is Applied 5/
Benonyl/ Benlate	S	>9590	0.5	OR	<1	MR, AP, MA, JU
Captafol/ Difolatan	S	5000	0.031 6/	OR	<1	MR, AP
Captan/ Orthocide	S	9000	0.13	OR	<1	MR, AP, MA, JU, JL
Dichlone/ Phygon	S	1300	0.047	OR	<1	MR, AP, MA
Dodine/ Cyprex	W	1000	0.9	OR	Soluble	MR, AP, MA, JL
Ferbam	SW	>17000	12.6 6/	CB	<1	AP, MA
Maneb	S	6750	1.0	OR, CB	<1	MR, AP, MA, JU
Thiram/TMTD	S	375	0.79 6/	OR	<1	AP, MA, JL
Zineb	S	>5200	0.5	CB	<1	AP, MA

1/ Where movement of insecticides in runoff from treated fields occurs, S denotes those chemicals that will most likely move primarily with the sediment; W denotes those that will most likely move primarily with the water; SW denotes those that will most likely move in appreciable proportion with both soil and water.

2/ Expressed as the lethal dose, or lethal concentration, to 50 percent of the test animals (LD_{50} or LC_{50}, respectively).

3/ 48- or 96-hour LC_{50} for bluegills or rainbow trout, unless otherwise specified.

4/ Following abbreviations used: OR - Orchards and CB - Cranberries.

5/ MR - March, AP - April, MA - May, JU - June, and JL - July.

6/ For catfish.

Monitoring for Pesticides in Surface Waters

The U.S. Geological Survey has been monitoring for pesticides at various stream gauging stations in Massachusetts and neighboring states for the past 10 to 15 years. Many of these stations are on major rivers and include:

Gauging Station	Drainage Area Sq. Mi.
Connecticut River near Northfield, MA	7,025
Connecticut River at Thompsonville, CT	9,661
Hoosic River below Williamstown, MA	203
Merrimack River above Lowell, MA	4,200
Nashua River at Ft. Devens, MA	184
Whitman River near Westminster, MA	21.7

In addition, the U.S. Geological Survey has tested for pesticides at several locations on small streams and ponds in the Sudbury River watershed in Marlborough and Sudbury. This program conducted in 1976 to 1978 included sampling and testing for physical, other chemical parameters, and for biological data. The pesticides and their derivatives tested for in this small stream survey include Aldrin, Chlordane, DDD, DDE, DDT, Dieldrin, Endosulfan, Endorin, Heptachlor, Heptachlor Epoxide, Lindane, Naphthalenes, Polychor, Mirex, Perthane, and Toxaphene. In this particular survey all test results were shown as 0.00 micrograms per liter (parts per billion). [1/] These samples were taken from June to November, the usual season for pesticide application.

Normally one expects similar test results at stream gauging stations on larger rivers for stream water samples. Sampling of stream bottom materials is more likely to indicate the presence of pesticides as indicated by test results published by the U.S. Geological Survey for Blackstone River at Manville, RI, in 1980 and for other locations. [2/]

Reasons for the lack of positive test results for pesticide in these testing programs include:

1. Low levels of pesticides are applied on a total watershed area basis. Agricultural and other lands where pesticides are applied are often only a small portion of the drainage area at a sampling station.
2. Sampling may not have been done at the most auspicious times, i.e., after pesticide applications when pesticide concentrations are expected to be highest.

1/ U.S. Geological Survey, Water Resource Data for Massachusetts and Rhode Island, Water Year 1979, Water Data Report MA-RI-79-1, prepared in cooperation with the states of Massachusetts and Rhode Island and with other agencies, 1980, pages 256 to 285.

2/ U.S. Geological Survey, Water Resource Data for Massachusetts and Rhode Island, Water Year 1980, Water Data Report MA-RI-80-1, prepared in cooperation with the states of Massachusetts and Rhode Island and with other agencies, 1981 and similar reports for earlier years and for neighboring states.

In addition to these monitoring efforts, state and regional agencies have also conducted pesticide monitoring programs. In the lake water quality program for White Island Pond by the Massachusetts Division of Fisheries and Wildlife samples from an inlet to this pond were tested for Dieldrin, a pesticide used in the local cranberry industry. This pond is located in the towns of Plymouth and Wareham and has a substantial quantity of cranberry bogs in the contributing watershed. This inlet was sampled in August 1976 and no Dieldrin was detected. 1/

As mentioned in Section 3.1.1 208 Water Quality Management Plans, the Montachusett Regional Planning Commission sampled a small pond within an orchard, drainpipes in the orchard, and streams above and and downstream of the orchard.

Also, an additional small orchard was monitored by sampling from a small ditch draining this orchard. The pesticide application program was obtained for both orchards in order to determine what to test for and when to sample.

Results of the detailed testing program which included testing for DDT, DDD, Dieldrin, Captan, Guthion, Sevin, Karathane, Dikor, Cupinex, were all shown as undetectable. Boron was detected in this testing program in rates as high as 0.2 parts per million. The 208 study concluded that the boron probably originated from a boron containing pesticide which had been recently used. 2/
One of the better pesticide monitoring techniques is to sample and test aquatic organisms such as fish which are at the top of the food chain. For certain pollutants including many pesticides each link in the food chain concentrates these substances so that each level has substantially higher concentrations than the level just below. The concentrations found in fish body fat can often be more than a thousand times greater than the initial concentrations in the ambient waters the fish came from. Shellfish have proven to be excellent subjects for pesticide monitoring. Freshwater mussels, for example, will filter tremendous quantities of water through their bodies in order to extract their food. In this process many pesticides, if present in the water or food, will be stored in the bodies of these shellfish.

Most of the pesticides, approved for use in agriculture today, degrade into less harmful by-products. The general trend has been towards materials which degrade quickly, within a few days, and away from substances such as DDT which persist for years in harmful forms.

1/ Whittaker, Gayle E., White Island Pond, Water Quality Study, August 1976-May 1978, Water Quality and Research Section, Mass. Division of Water Pollution Control, Westborough, MA, June 1980, p. 37.

2/ Montachusett Regional Planning Commission, Montachusett-Nashua Areawide Water Quality Management Program, for the U.S. Environmental Protection Agency, Fitchburg, MA, January 1979, pp. A-13 - A-20.

The amount of pesticide monitoring by state agencies has greatly diminished since the early seventies. A lack of funds is usually cited for this situation but the following comments have bearing in this situation also:

1. A nationwide change to more biodegradeable pesticides has occurred.

2. Statewide use of pesticides for all purposes has greatly diminished. For example, in the period from World War II to the sixties, massive amounts of pesticides were applied in insect control programs. Annual aerial spraying for mosquito control is the primary example that comes to mind.

3. Laboratory testing for the new pesticide compounds now being used is more difficult and expensive.

Pesticides in Groundwater

As recent news stories in the local and major newspapers and on television indicate, one of the most important water quality issues involving agriculture in Massachusetts is pesticide contamination of groundwater.

Massachusetts Department of Environmental Engineering has begun a program to test samples from hundreds of wells in Western Massachusetts for Ethylene Dibromide (EDB). EDB test results for municipal wells have forced West Springfield and Deerfield to shut down public water supply wells. EDC concentrations in three public wells exceeded the state safety standards for EDB in drinking water of 0.1 parts per billion (ppb). EDB was used in the tobacco industry as a soil fumigant. Its use is now banned as a soil fumigant by EPA and also less than 200 acres of tobacco are now grown in Massachusetts. The EDB contamination is, therefore, an example of a substance which is no longer used but sufficient quantities to cause contamination problems are in the local environment.

Aldicarb, Temik, contamination has been found in private and public wells in Western Massachusetts. This pesticide is still in use; however, the Massachusetts Department of Food and Agriculture has imposed further restrictions on the use of this substance. These further restrictions are:

1. A prohibition on the use of Temik 15G within 1,000 feet of a public or private well.

2. All use of Temik 15G must be preceeded by prior notification of the Department of Food and Agriculture. [1/]

1/ Cooperative Extension Service, Massachusetts Pesticide News, April 1984, Vol. 8(2), R.G. Van Driesche, Department of Entomology, University of Massachusetts, Amherst, MA.

A key problem identified with these contamination problems is lack of knowledge. There is insufficient information on the affected aquifers; such as their size, volume, flow and other characteristics and how they are affected including amount, concentrations, and movement of contaminants within these aquifers. Information on which pesticides were used, where, and how much is lacking. The transport mechanisms of pesticides from the site surface to underlying aquifer are inadequately known as is the degradation of pesticides at various stages along the transport route.

Conclusions

In general, caution should be used when handling or applying pesticides. Many of these substances are harmful to humans and the detailed instructions for each pesticide should be followed.

Harmful pesticide concentrations in our water resources can result from accidental spills and inadequate disposal of containers. Also, insufficient application information or disregard of application instructions may lead to contamination problems. An example of this is the groundwater contamination resulting from aldicarb application on potatoes in the Whately and Deerfield area. Tests by Massachusetts DEQE indicate the presence of aldicarb at concentrations close to and above allowable maximum contamination levels for drinking water, set by EPA and Massachusetts, in private wells.[1/]

For these substances more information is needed on where these materials should or should not be applied.

1/ News stories published in August 1983 in area newspapers including the Morning Union of Springfield, MA and the Greenfield Recorder of Greenfield, MA.

MASSACHUSETTS AGRICULTURAL WATER QUALITY STUDY

WORKING PAPER NO. 3

Erosion Estimates on Agricultural Land

MASSACHUSETTS RIVER BASIN PLANNING PROGRAM

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

ECONOMICS RESEARCH SERVICE

FOREST SERVICE

in cooperation with

MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING

Nov 1981

MASSACHUSETTS AGRICULTURAL WATER QUALITY STUDY

WORKING PAPER #3

EROSION ESTIMATES ON AGRICULTURAL LAND

TABLE OF CONTENTS

1. INTRODUCTION

This paper presents erosion estimates for agricultural land in 49 Massachusetts cities and towns. The criteria used to select these 49 municipalities was presented in Working Paper #2, Agricultural Land Use and Livestock Statistics, prepared produced earlier in this project.

In addition to the erosion estimates, a methodology is presented to determine unacceptable rates of erosion from a water quality perspective.

This methodology was developed to predict changes in total phosphorus in downstream waters due to soil erosion. A further refinement of this methodology would be to modify it to predict biologically available phosphorus instead of total phosphorus. Biologically available phosphorus is that portion of the total phosphorus which is available to support plant growth in lakes and ponds and consists of all the soluble phosphorus and usually from 5 to 30 percent of the particulate phosphorus. Particulate phosphorus is that phosphorus which is adsorbed to the surface of soil particles. [1/] Further study will be needed to calculate the actual phosphorus loadings and thresholds for any potential project area.

2. Unacceptable Levels of Erosion

In conservation planning work the conservation districts, SCS employees, and others attempt to maintain the soil resource so that soil productivity will not be lost in the future. A soil parameter, T Factor, has been developed for comparison of erosion rates with a standard. T Factor can be defined as the maximum tolerable soil loss in tons per acre per year and still maintain soil productivity indefinitely into the future. For soils in Massachusetts, T Factors vary from 1 to 5 tons per acre per year with 3 tons per acre per year being the value for most soils. Over 85 percent of the Massachusetts soil series classified as Prime Farmland Soils and Soils of Statewide or Local Importance for Agriculture have a T Factor of 3 tons per acre per year.

This study was charged with defining unacceptable rates of erosion from a water quality perspective. These unacceptable rates should be based on the soil erosion contribution to nutrient levels in water resources. Nitrogen compounds, particularly nitrates, and phosphorus are the nutrients considered for correlation with soil loss. Further study led us to concentrate on phosphorus and abandon any further work with nitrogen because "Soluble pollutants such as nitrate are not related to soil losses at all,

1/ Lee, G.F., R.A. Jones and W. Rast, "Availability of Phosphorus to Phytoplankton and its Implications for Phosphorus Management Strategies, Chaper 11," Phosphorus Management Strategies for Lakes, Proceedings of the 1979 Conference, edited by R.C. Luehr, C.S. Martin, W. Rast, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1980.

and losses in surface runoff are relatively small compared to the quantities in subsurface (interflow) and seepage." 1/

Two equations were developed which relate erosion rates on cropland and phosphorus content in sediment to the amount of cropland in a given watershed in simplistic terms.

Equation (1) $J = ER \times DR \times CR$

Where: J = the average annual total phosphorus concentration from the area of cropland under consideration in mg/l.

ER = Erosion Rate in tons/acre/year

DR = Sediment Delivery Ratio which is the ratio of sediment delivered to the soil loss which occurred in the field expressed as a decimal.2/

CR = Average yearly concentration of total phosphorus in sediment divided by average yearly runoff.

For conditions and assumptions used in this paper

$$CR = \frac{1.5 \text{ lb. } P_tT \times 1 \times 0.3677 \text{ mg acre ft.}}{\text{ton sediment} \times 1.83 \text{ ft.} \times \text{liter lb.}}$$

$$CR = 0.301 \ \frac{\text{mg}}{\text{liter}} \times \frac{\text{acre}}{\text{ton}}$$

Given: 1. Average concentration of total phosphorus per ton of sediment (assumed) = $\frac{1.5 \text{ lbs. } p_t}{\text{ton sediment}}$

See the technical appendix for background information on this assumption.

2. Average yearly runoff (average value for state = 22 inches = 1.83 feet.

3. Conversion Factor =

$$453{,}600 \ \frac{\text{mg}}{\text{lb.}} \times \frac{1 \text{ acre}}{43560 \text{ sq. ft.}} \times \frac{1 \text{ cu. ft.}}{28.32 \text{ liters}} =$$

$$0.3677 \ \frac{\text{mg}}{\text{liter}} \quad \frac{\text{acre ft.}}{\text{lb.}}$$

For specific watersheds the delivery ratio, lbs. p per ton of sediment and the average annual runoff could be modified with actual local values.

1/ Walter, Michael F., Tammo S. Steenhuis, and Douglas A. Haith, "Soil and Water Conservation Practices for Pollution Control," a paper presented at 1977 Winter Meeting of American Society of Agricultural Engineers, Chicago, Illinois, December 1977, p. 5.

2/ Sediment Delivery Ratio Curve used is Figure 6-2. Sediment delivery ratio vs. size of drainage area, SCS National Engineering Handbook, Section 3, Sedimentation, USDA-SCS Washington, D.C., 1971.

Equation (2) $0.015(W-x) + Jx = 0.025W$

Where: W = the total watershed area in acres x = the area of cropland in acres, in watershed W. Does not include hayland, orchards and other agricultural land which have an essentially permanent soil cover.

The equation is not valid for x = 0.

The mean annual total phosphorus concentration for streams would be 0.015 mg/l for a totally undeveloped watershed in New England.[1/]

Equation 2 sets the phosphorus loading from the forested undeveloped portion of the watershed plus the phosphorus loading from the cropland in the watershed equal to 0.025 mg/l, the average annual total phosphorus concentration at which eutrophication problems accelerate in lakes, ponds, and reservoirs. This is an approximate value because lake eutrophication depends upon many other factors including lake volume and area, and annual inflow.

This value was selected because of the great number of lakes, ponds and reservoirs in Massachusetts including impoundments on most major rivers. Values listed in the Agricultural Waste Management Field Manual, USDA, Soil Conservation Service, August 1975, on page 2-5 are 0.025 mg/l for lakes and reservoirs, 0.05 mg/l and 0.10 mg/l for streams and rivers.

Equation 2 may be transformed to:

Equation 2a $x\ (J-0.015) = 0.01W$

or

Equation 2b $J = 0.01\frac{W}{x} + 0.015$

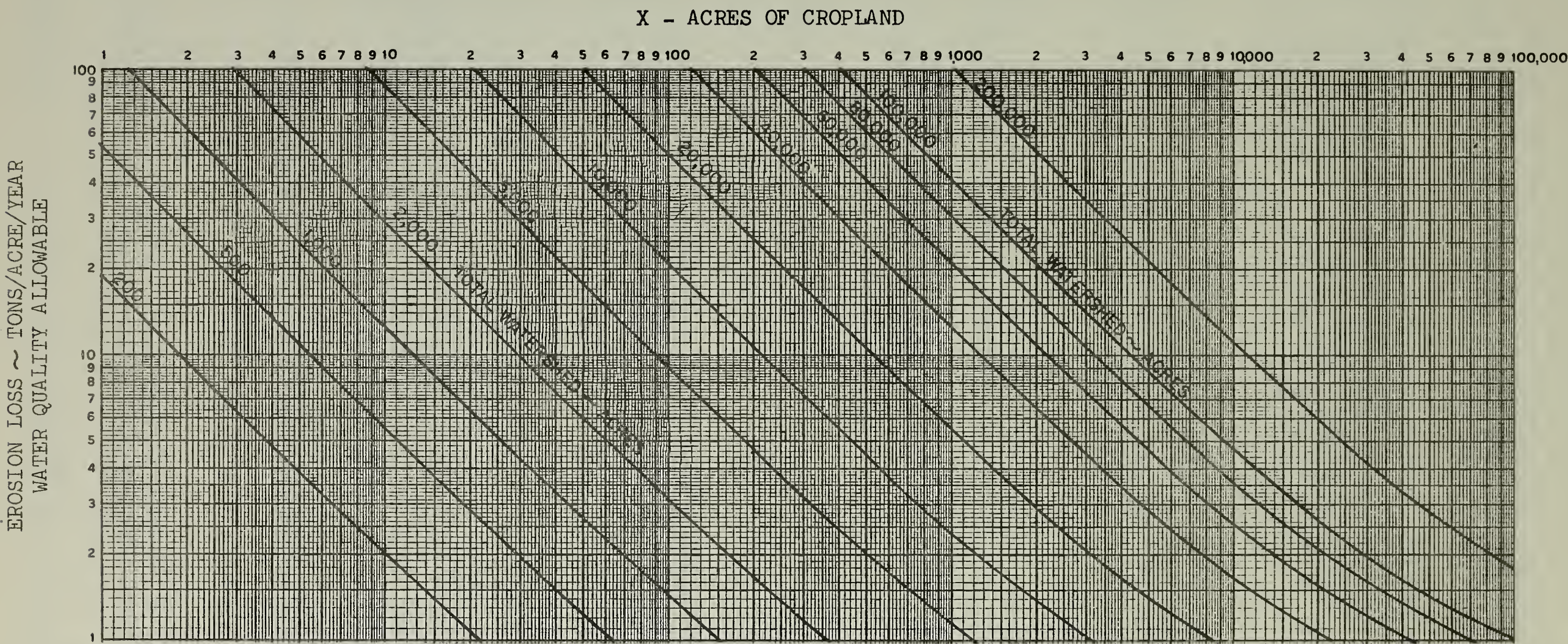
To determine the average allowable erosion rate for the cropland in a watershed solve equation 2b for J and then solve for ER in a rearranged equation 1 $ER = \frac{J}{DR \times CR}$

Figure 1, Maximum Erosion Loss, Tons/Acre/Year, Allowable on X Acres of Cropland to Meet and Not Exceed Annual Average Phosphorus Allowable Concentration, permits rapid determination of allowable erosion loss for various cropland acreages and watershed areas based on Equations 1 and 2.

1/ Omernik, James M., The Influence of Land Use on Stream Nutrient Levels, p. B251-150, Environmental Research Lab., U.S. EPA, Corvallis, Oregon, January 1976 and Nonpoint Source - Stream Nutrient Level Relationships: A Nationwide Study, EPA-600/3-77-105, by James M. Omernik, Corvallis Environmental Research Lab., U.S. EPA, Corvallis, Oregon, September 1977.

FIGURE 1

MAXIMUM EROSION LOSS,TONS/ACRE/YEAR, ALLOWABLE ON X ACRES OF CROPLAND TO MEET & NOT EXCEED ANNUAL AVERAGE PHOSPHORUS ALLOWABLE CONCENTRATION (0.025 mg/1).



Given: 1 ton sediment contains 0.075% Phosphorus(1.5 lb. P), sediment delivery curve from SCS NEH-3 Sedimentation Handbook, average annual runoff ≈ 22 inches, maintain Water Resource P_t concentration ≤ 0.025 mg/l P_t, average annual P_t concentration from forested watersheds ≈ 0.015 mg/l P.

Plot from $x(j-0.015) = 0.01W$ where x = acres of cropland; W = watershed area in acres; j = average yearly Phosphorus concentration(mg P/1) = erosion loss(tons/acre) X Delivery Ratio X P. Content of sediment ÷ annual runoff.

Example: A 20,000 acre watershed with 1,400 acres of cropland - Start at bottom edge, find 1,400 acres of cropland, move vertically to 20,000 acre watershed curve. From this intersection move horizontally to left margin and read water quality allowable erosion rate of 4.0 tons/acre.

Table 1 lists the allowable cropland erosion rate, tons per acre, for the selected municipalities for their cropland acreage based on using the municipal total area as the watershed area. The maximum allowable erosion rate varied from 1.0 to 75.9 tons per acre per year. It is assumed that in using this allowable erosion rate based on water quality requirements that planners would recommend that the maximum erosion rate be equal to or less than the T factor or the allowable erosion rate based on water quality criteria whichever is less.

The methodology was developed to answer the question, In this field in this watershed what erosion rate will cause water quality problems downstream and what lesser rates will not? With this method an allowable erosion rate is determined for all the cropland, exclusive of hayland, orchards, and nursery land in a watershed. The allowable erosion rate for one field is dependent upon what is happening in all the other crop fields in the watershed. In individual fields the actual erosion rate can be compared to the watershed allowable erosion rate and an attempt can be made to reduce the actual erosion rates on these fields to the allowable rate or less.

3. Erosion Estimates

Sheet and rill erosion was estimated for all the agricultural land in 49 selected municipalities. These erosion rates were computed using the Universal Soil Loss Equation. See the technical appendix for a detailed explanation of the methodology involved. Table 1, Erosion Loss on Agricultural Land for 49 Selected Municipalities, presents the annual erosion in tons and the average erosion rate for hayland, pasture, cranberries, orchards and nurseries, and cropland for each municipality.

Erosion estimates were made for 146,482 acres of agricultural land in the selected municipalities. The annual average erosion rate for these areas is 2.4 tons per acre. The corresponding rate for the 75,072 acres of hayland and pasture is 0.4 tons per acre, for the 4,052 acres of orchard and nurseries is 0.5 tons per acre, and for the 63,522 acres of cropland is 4.9 tons per acre. There is an insignificant amount of erosion expected from cranberry bogs because of their permanent vegetation, level surfaces and the intensive water management they are subject to.

Values for town average annual erosion rates on cropland range from a high of 18.0 tons per acre in Colrain to a low of 1.7 tons per acre in Hadley. Average erosion values from hayland, pasture, orchards and nurseries for the selected towns are all less than 1 ton per acre per year. Sediment problems can be expected downstream of cropland but not from these other types of agricultural land.

MASSACHUSETTS AGRICULTURAL WATER QUALITY STUDY

Table 1: Estimated Erosion Loss on Agricultural Land for 49 Selected Municipalities

Basin No. and Name 1/	City/Town Name	Total Area 2/ Ac.	Hayland Area Ac.	Hayland Annual Erosion Tons	Hayland Ave. Annual Erosion Tons/Ac.	Pasture Area Ac.	Pasture Annual Erosion Tons	Pasture Ave. Annual Erosion Tons/Ac.	Cranberries Area Ac.	Cranberries Annual Erosion Tons	Orchards/Nurseries Area Ac.	Orchards/Nurseries Annual Erosion Tons	Orchards/Nurseries Ave. Annual Erosion Tons/Ac.	Cropland Area Ac.	Cropland Annual Erosion Tons	Cropland Ave. Annual Erosion Tons/Ac.	Cropland W.Q. Allowable Crop. Ero. Rate Tons/Ac./Yr. 3/	Ave. Crop. Ero. Rate Exceeds Allowable W.Q. Erosion Rate	Ave. Crop. Erosion Rate Exceeds 3 Tons/Ac./Yr. 4/
1. Hoosic	Adams	14,520	351	131	0.4	1,115	538	0.5	-	-	50	25	0.5	556	7,126	12.8	6.3	*	*
	Cheshire	17,858	1,105	567	0.5	2,034	1,202	0.6	-	-	-	-	-	653	10,731	16.4	6.9	*	*
	Williamstown	30,016	1,065	359	0.3	2,311	1,451	0.6	-	-	64	31	0.5	1,223	11,592	9.5	7.2	*	*
2. Housatonic	Gr. Barrington	29,088	669	161	0.2	1,375	428	0.3	-	-	41	16	0.4	1,365	6,310	4.6	6.3		*
	Lee	17,376	12	6	0.5	203	67	0.3	-	-	-	-	-	1,010	5,455	5.4	4.4	*	*
	New Marlborough	30,260	890	258	0.3	1,307	453	0.3	-	-	2	1	0.7	1,108	8,334	7.5	8.0		*
	Sheffield	31,417	669	335	0.5	2,626	844	0.3	-	-	61	27	0.4	3,719	13,058	3.5	2.8	*	*
3. Deerfield	Ashfield	25,776	671	363	0.5	1,853	1,079	0.6	-	-	119	100	0.8	344	5,550	16.1	20.3		*
	Colrain	27,664	134	41	0.3	2,169	1,743	0.8	-	-	157	115	0.7	994	17,848	18.0	8.1	*	*
	Conway	24,032	1,003	410	0.4	1,055	578	0.5	-	-	17	5	0.3	389	5,316	13.7	16.8		*
	Greenfield	14,764	550	141	0.3	484	168	0.3	-	-	7	2	0.3	1,069	4,036	3.8	3.5	*	*
	Shelburne	15,460	360	200	0.6	1,241	1,075	0.9	-	-	419	314	0.7	627	8,200	13.1	6.2	*	*
4. Westfield	Cummington	14,817	366	110	0.3	451	185	0.4	-	-	18	3	0.2	368	4,226	11.5	9.6	*	*
	Southwick	19,932	658	222	0.3	1,427	556	0.4	-	-	71	7	0.1	2,008	9,878	4.9	2.8	*	*
	Westfield	29,858	571	189	0.3	1,155	429	0.4	-	-	110	21	0.2	1,709	4,090	2.4	5.3		
6. Connecticut Valley	Agawam	15,624	219	74	0.3	325	111	0.3	-	-	73	17	0.2	1,989	7,742	3.9	2.2	*	*
	Amherst	17,662	468	95	0.2	1,906	649	0.3	-	-	227	112	0.5	1,397	6,188	4.4	3.4	*	*
	Deerfield	21,036	620	141	0.2	974	461	0.5	-	-	69	26	0.4	3,469	12,158	3.5	1.9	*	*
	Easthampton	8,701	509	106	0.2	192	63	0.3	-	-	99	69	0.7	853	5,423	6.4	2.4	*	*
	Granby	17,925	1,331	279	0.2	531	268	0.5	-	-	45	5	0.1	990	3,294	3.3	4.7		*
	Hadley	16,652	1,550	270	0.2	560	186	0.3	-	-	79	30	0.4	4,595	7,927	1.7	1.2	*	
	Hatfield	10,598	308	31	0.1	149	22	0.1	-	-	9	1	0.1	2,987	5,566	1.9	1.0	*	
	Northampton	22,649	425	134	0.3	422	163	0.4	-	-	25	10	0.4	2,298	4,572	2.0	2.9		
	Northfield	22,392	227	30	0.1	983	390	0.4	-	-	-	-	-	2,223	7,351	3.3	3.0	*	*
	Southampton	18,912	49	12	0.2	1,552	483	0.3	-	-	18	13	0.7	895	2,250	2.5	5.6		
	Whately	13,012	904	294	0.3	214	71	0.3	-	-	20	10	0.5	1,662	3,036	1.8	2.1		
8. Chicopee	Barre	28,976	536	323	0.6	1,137	768	0.7	-	-	-	-	-	1,040	7,831	7.5	8.1		*
	Belchertown	35,468	964	293	0.3	1,533	575	0.4	-	-	381	216	0.6	813	3,523	4.3	13.0		*
	Hardwick	26,148	625	439	0.7	1,488	1,052	0.7	-	-	5	1	0.3	921	7,590	8.2	7.9	*	*
	Monson	28,964	68	17	0.3	1,056	445	0.4	-	-	117	38	0.3	561	2,328	4.1	14.7		*
	New Braintree	13,523	765	355	0.5	1,266	764	0.6	-	-	27	8	0.3	1,176	10,602	9.0	2.9	*	*
	North Brookfield	14,116	830	416	0.5	800	587	0.7	-	-	159	64	0.4	812	6,515	8.0	4.3	*	*
	Spencer	21,844	799	472	0.6	623	472	0.8	-	-	47	17	0.4	835	10,687	12.8	7.1	*	*
	Warren	17,628	514	148	0.3	914	392	0.4	-	-	99	66	0.7	511	3,647	7.1	8.5		*
9. French and Quinebaug	Brimfield	22,716	404	186	0.5	699	337	0.5	-	-	106	58	0.5	396	1,690	4.3	15.1		*
	Charlton	27,901	646	426	0.7	1,027	785	0.8	-	-	87	56	0.6	829	7,964	9.6	9.7		*
	Dudley	13,964	519	345	0.7	607	470	0.8	-	-	13	4	0.3	1,131	9,819	8.7	3.2	*	*
	Oxford	17,480	203	69	0.3	392	205	0.5	-	-	110	88	0.8	519	3,714	7.2	8.4		*
	Southbridge	13,193	232	124	0.5	154	120	0.8	-	-	-	-	-	220	3,341	15.2	13.6	*	*
10. Nashua	Sterling	20,176	954	375	0.4	572	361	0.6	-	-	722	303	0.4	613	2,934	4.8	8.5		*
11. Blackstone	Sutton	22,032	750	335	0.4	553	313	0.6	-	-	202	104	0.5	930	4,145	4.5	6.4		*
	Uxbridge	19,145	344	153	0.4	158	70	0.4	-	-	-	-	-	920	6,634	7.2	5.5	*	*
12. Merrimack	Haverhill	23,012	1,424	620	0.4	599	242	0.4	-	-	35	17	0.5	472	2,734	5.8	12.9		*
25. Buzzards Bay and Mt. Hope Bay	Carver	27,504	-	-	-	102	14	0.1	2,944	0	2	-	0.1	101	372	3.7	75.9		*
	Dartmouth	40,037	39	12	0.3	1,592	394	0.2	51	0	55	13	0.2	2,091	5,359	2.6	6.2		
	Rehoboth	30,493	12	4	0.3	928	241	0.3	-	-	9	1	0.1	2,649	6,138	2.3	3.6		
	Westport	37,036	-	-	-	1,042	369	0.4	-	-	16	6	0.4	3,229	11,513	3.6	3.9		*
26. Taunton	Bridgewater	18,183	1,046	201	0.2	181	24	0.1	12	0	30	3	0.1	1,063	3,110	2.9	4.4		
	Middleborough	46,418	476	106	0.2	1,201	298	0.2	824	0	35	9	0.3	1,190	2,401	2.0	12.8		
Totals		1,093,958	27,834	10,378	-	47,238	22,961	-	3,831	0	4,057	2,032	-	63,522	311,848	-	-		
Average		-	-	-	0.4	-	-	0.5	-	-	-	-	0.5	-	-	4.9	-		

1/ Only basins which contain selected municipalities are listed.

2/ MacConnell, William P., Remote Sensing 20 Years of Change in Franklin County, Massachusetts, 1952-1972, Massachusetts Agricultural Experiment Station, University of Massachusetts, Amherst, Massachusetts, 1975, and other similar publications by MacConnell et al.

3/ The Water Quality Allowable Cropland Erosion Rate is computed from the municipal total area, the cropland area and the assumption that a ton of sediment contained 1.5 pounds of phosphorus.

4/ The "T" Factor, maximum tolerable soil loss, for most Massachusetts soils is 3 tons per acre per year. Over 85 percent of the approximately 400 soil mapping units which are classified as Prime Farmland or of Statewide or Local Importance for Agriculture in Massachusetts have T factors of 3 tons per acre.

Appendix A:

TECHNICAL APPENDIX

A.1 Erosion Estimates

Erosion estimates on agricultural land were made using the Universal Soil Loss Equation (USLE) which estimates sheet and rill erosion caused by rainfall.

"The soil loss equation is

$$A = RKLSCP$$

where

A is the computed soil loss per unit area, expressed in the units selected for R. In practice, these are usually so selected that they compute A in tons per acre per year, but other units can be selected.

R, the rainfall and runoff factor, is the number of rainfall erosion index units, plus a factor for runoff from snowmelt or applied water where such runoff is significant.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6 ft. length of uniform 9 percent slope continuously in clean-tilled fallow.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6 ft. length under identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9 percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.1/

1/ Wischmeier, W. H. and D. D. Smith, "Predicting Rainfall Erosion Losses - A Guide to Conservation Planning," USDA, Science and Education Administration in cooperation with Purdue Agricultural Experiment Station, Agricultural Handbook No. 537, Washington, D.C., 1978, p. 4.

In computations L & S are combined into one term (LS), called the Topographic Factor, which is a function of both slope and slope length. In Massachusetts the range of numerical values for the various parameters of the USLE for agricultural land is:

Parameter	Range of Numerical Values	Relative Range (Highest Value Divided by Lowest)
R	125 - 150	1.2
K	0.10 - 0.64	6.4
LS	0.05 - 18.63 1/	373
C	0.001 - 1.	1,000
P	0.25 - 1	4.

An approximate method has been developed to estimate erosion for pasture, hayland, orchards and nursery land. Erosion estimates for these types of agricultural land were plotted against percent slope using 72 USLE estimates from the 1977 Land Inventory Monitoring and the 1979 Natural Resource Inventory programs and 50 USLE estimates from the Massachusetts Water Resources Study. These estimates were generally low values because the permanent vegetation associated with these types of agricultural land necessitated the use of low cover factors (c). Envelope curves were drawn that included greater than 90 percent of the data points. These envelope curves were drawn to coincide with soils slope classes:

Slope Class	Slope %	Annual Erosion Rate tons/acre
A	0-3	0.1
B	3-8	0.3
C	8-15	0.7
D,E,F	15 & steeper	1.5

For the purposes of this study, estimates of sheet and rill erosion on pasture, hayland, orchards and nurseries were estimated using this table.

For cropland, erosion estimates were computed for individual fields using the USLE. These computations were done using all available soils and other information gathered during the land use phase of the study. Spot checks of these computations were made in the field to guide personnel and to check the reasonableness of the answers. In the process of field checking these sheet and rill erosion estimates, personnel also collected information on gully and streambank erosion on agricultural lands.

1/ The LS values were computed for these slope and slope length conditions: Low 0% slope and 25 foot length and High 25% and 1,000 foot length.

A.2 Unacceptable Levels of Erosion

Earlier in this paper two equations were presented which relate phosphorus content in sediment and erosion rates on cropland to the acreage of cropland in a given watershed.

The following presents some of the background information and considerations used in selecting the value of 1.5 pounds total phosphorus per ton of sediment used in parameter CR.

Phosphorus content of in-place soils from selected sites in Vermont and Massachusetts is presented in Tables A-1 and A-2. Phosphorus content of lake bottom materials for 10 Massachusetts lakes is shown in Table A-3. The lake bottom material data was collected by Massachusetts Division of Water Pollution Control personnel and published in various lake water quality study reports. [1/]

From a water quality standpoint the phosphorus content of sediment, and not of in-place soils is more important. Sediment at a downstream point in a river system equals all the originally eroded materials less those materials which have already dropped out at various depositional locations. These deposited materials are usually the coarser soil materials. Gravel sized particles drop out first, sand sizes second and silt sizes afterward. In a given volume of soil most of the phosphorus would be associated with the finer soil particles, clays and silts, and organic materials. The gravels and sands retain little of the original phosphorus in that given volume of soil. As the coarser materials in sediment drop out first, it could therefore be expected that the phosphorus content in a volume of sediment to increase in a downstream direction as more of the

---

1/ Whittaker, Gayle E., White Island Pond Water Quality Study, August 1976 - May 1978, Massachusetts Division of Water Pollution Control, Westborough, Massachusetts, June 1980 and eight other similar publications.

TABLE A-1 PHOSPHORUS CONTENT OF SELECTED SOILS IN VERMONT 1/

Soils	Total Phosphorus ppm 2/	Percent	lb. P_T/ton
Buckland	81.3	0.0081	0.16
Buckland	340.	0.034	0.68
Calais	530	0.053	1.06
Hadley	900	0.09	1.8
Hartland-Buxton	693	0.069	1.38
Hartland-Agawam	1,097.5	0.110	2.2
Vergennes	600	0.060	1.2
Colrain	850	0.085	1.7
Windsor	1,650	0.165	3.3

1/ Data provided by Vermont SCS staff with the note that cropping patterns and management practices exert a great influence on the phosphorus content of cropland soils as this data shows.

2/ ppm - parts per million

TABLE A-2 PHOSPHORUS CONTENT OF SELECTED SOILS IN MASSACHUSETTS 1/

Sample and Description	Total Phosphorus mg/kg	%	lbs P_T/ton
1. Fredon soil, crop field in Lanesborough	930	0.093	1.86
2. Fredon soil, undisturbed field border adjacent to #1	235	0.0235	0.47
3. Tunbridge-Lyman soil, crop field in Lanesborough	10	0.001	0.02
4. Tunbridge-Lyman soil, undisturbed field border adjacent to #3	249	0.0249	0.5
5. Recent Brook Alluvium	225	0.0225	0.45

1/ Sampled by SCS personnel on 3/12/81 and tested by Lycott Environmental Research, Inc., Southbridge Massachusetts.

TABLE A-3

PHOSPHORUS CONTENT OF BOTTOM MATERIALS OF SELECTED LAKES IN MASSACHUSETTS SAMPLED [1/]

Lake Or Pond	Water Depth at Sampling Station Ft.	Sampling Date	Total Phosphorus Individual Readings mg/kg	Average for the Lake mg/kg	%	lbs P_t/ton
Pontoosuc	35	3-23-76	1,300	1,300	0.13	2.6
Winthrop	20	2-21-79	1,600			
	20	7-24-79	138			
	6	7-24-79	83	607	0.06	1.2
Norton	9.5	3-3-76	2,700			
	7	3-3-76	2,400	2,550	0.255	5.1
Waushakum	50	2-25-76	165	165	0.0165	0.33
Quaboag	8	8-74	250			
	8	8-74	50	150	0.015	0.30
Quacumquasit	72	8-74	75			
	72	8-74	200	138	0.0138	0.27
Attitach	25	3-9-78	1,100	1,100	0.11	2.2
Mattawa	35	3-8-76	2,000	2,000	0.20	4.0
Indian	20	2-76	111	111	0.011	0.22
White Island	14	3-14-78	690			
	10	3-14-78	860			
	13	3-14-78	710	753	0.075	1.5
Averages				887	0.0887	1.77

1/ These data were published in White Island Pond Water Quality Study, August 1976 - May 1978, by Gayle E. Whittaker, Massachusetts Division of Water Pollution Control, Westborough, MA, June 1980, and eight other similar publications.

In May 1981 a storm was monitored on Town Brook at Bridge Street in Lanesborough. The drainage area at this station is 10.7 square miles. Both streamflow and water quality test data were selected for this event. Water quality data are presented below:

Sample Number	Time of Sample May 12, 1981 A.M.	Total Phosphorus mg/l	Suspended Sediment mg/l
1	0215	0.10	114
2	0315	0.28	207
3	0415	0.33	320
4	0515	0.27	220
5	0615	0.15	105
6	0715	0.09	62
7	0815	0.07	40

Total phosphorus discharge in this event was 35.0 pounds (15.9 kg) while the total suspended sediment was 13.8 tons. This is 2.54 pounds total phosphorus per ton of sediment. The total volume of this storm was 79.25 acre feet of runoff which equals 0.14 inches on the contributing drainage area.

Not all of the 2.54 pounds total phosphorus per ton of suspended sediment comes from erosional sources. There are approximately 180 dairy cattle, 20 beef cattle and 10 horses in the Town Brook drainage area. These animals probably contribute to the phosphorus loading. Other possible phosphorus sources are the rural residences and atmospheric loading. Considering these other sources it was estimated that the total phosphorus from erosional sources is probably in the range of 1.5 to 2 pounds per ton of suspended sediment for this storm event.

Table A-4 presents sediment and total phosphorus data for over 60 storm events for two small, agricultural watersheds in Georgia. Average phosphorus in the location in northern Georgia where this storm data was developed is presented in Figure 4-5, Loading Functions for Assessment of Water Pollution from Nonpoint Sources, A.D. McElroy, S.Y. Chin, J.W. Hebgin, A. Aleti, and F.W. Bennett, EPA-600/2-76-151, Washington, D.C., May 1976. This figure was listed

as coming from "Fertilizers and Lime in the United States," C.A. Parker et al, USDA Miscellaneous Publication No. 586, 1946. On this figure the average phosphorus content in Massachusetts in the first foot of soil ranges from 0.10 to 0.19 percent phosphoric acid, P_2O_5, which is 0.04 to 0.08 percent as phosphorus. These are, of course, average figures but they indicate that Massachusetts soils have generally twice the phosphorus content of the Georgia soils. The total phosphorus per ton of sediment values listed in Table A-4 vary from 1.62 to 2.85 pounds total phosphorus per ton of sediment.

At this time the estimate of pounds of total phosphorus per ton of sediment as used in this methodology can only be roughly estimated. Therefore, we would use 1.0, 1.5, 2.0 or other approximate value in our calculations. In this paper, we have selected 1.5 pounds of total phosphorus per ton of sediment as the most reasonable value to be used for Massachusetts at this time. A value of 1.0 appears to be too low when our available information is considered and we do not now have sufficient data to use a value as high as 2.0. It would be useful to attempt to further refine and define this parameter in future detailed surveys.

TABLE A-4 - Summary of Total Phosphorus and Total Sediment in Runoff Events on Small Upland Piedmont Agricultural Watersheds, near Athens, Georgia 1/

Watershed 2/	Number of Runoff Events	Dates	Total Sediment kilograms	Total Phosphorus kilograms	Total Phosphorus - Total Sediment Percent	Total Phosphorus - Total Sediment lbs/ton
P-2	29	4-74 to 5-75	2801.2	2.8819	0.1029	2.06
P-2	11	5-75 to 9-75	6748.5	5.4503	0.0808	1.62
P-4	23	5-74 to 5-75	1636.3	1.5103	0.0923	1.85
P-4	4	5-75 to 9-75	933.4	1.3302	0.1425	2.85

1/ C.N. Smith, R.A. Leonard, G.W. Langdale and G.W. Bailey, Transport of Agricultural Chemicals from Small Upland Piedmont Watersheds, EPA-600/3-78-056, Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Athens, GA, May 1978, pp 448, 454, 460 and 463.

2/ P-2 is 3.2 acres and P-4 is 3.5 acres.

APPENDIX B: BEST MANAGEMENT PRACTICES

Introduction

The Best Management Practices listed in this appendix are presented for approval by Massachusetts Department of Environmental Quality Engineering (DEQE), the designated statewide water quality management agency. Once approved by DEQE the practices on the list shall be considered appropriate for reducing water quality problems stemming from agricultural sources.

At this point it is useful to define a Best Management Practice, therefore:

> A Best Management Practice is a practice or combination of practices that is determined by the Massachusetts Department of Environmental Quality Engineering to be the most effective and practicable means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.

Best Management Practices

The following Best Management Practices (BMP's) have been selected to reduce water quality problems steming from agricultural sources.

There are 16 BMP's listed and each BMP can be further broken down into one or more components. There are a total of 57 separate components many of which are used in more than one BMP. Fifty-five of these components are selected from the SCS National Handbook of Conservation Practices. The name and number listed for component is the practice name and code number from this national handbook.

The two exceptions are practices, 384, Fertilizer Management, and 514, Pesticide Management, which originate with the Extension Service. Technical assistance for these two practices will be furnished by the Extension Service.

This listing of BMP's closely follows the BMP's selected for the Westport River Rural Clean Water Program (RCWP) in Bristol County, Massachusetts. Additional BMP's have been added to the Westport River RCWP listing to produce this statewide listing. These additional BMP's are needed for situations which are either not present or not very important to water quality in the Westport River.

BMP-1 PERMANENT VEGETATIVE COVER

A. Purpose To protect the soil and prevent the pollution of water from agricultural or silvicultural non-point sources.

B. Applicability To farm land subject to water erosion to be established in permanent vegetative cover to prevent water pollution.

C. Description The practice consists of the application of minerals and seeds, seedbed preparation, seeding and fencing. Items not considered part of this practice include:

1. Clearing of rocks or other obstructions.

2. Vegetative cover which includes only legumes.

The acreage seeded must be protected from grazing by domestic livestock until the stand is well established. Also, the vegetative cover should be maintained for some minimum lifespan.

D. Components

1. Fencing - 382
2. Pasture and hayland management - 510
3. Pasture and hayland planting - 512

BMP-2 ANIMAL WASTE CONTROL SYSTEM

A. Purpose To prevent the pollution of water by animal wastes.

B. Applicability To areas on farmland where animal wastes from the farm constitutes a significant water pollution hazard.

C. Description This practice provides facilities for the storage and handling of livestock and poultry waste and for the control of surface runoff water to permit the recycling of animal waste onto the land in such a manner as to abate pollution which would otherwise result from livestock or poultry operations. Animal waste storage facilities include aerobic and anaerobic lagoons, liquid manure tanks, holding ponds, collection basins, and settling basins. Surface runoff components can include diversions, channels, waterways, outlet structures, piping, land shaping, and similar measures. Other permanently installed equipment, needed as an integral part of the system are roof gutters, fencing and vegetative cover and for leveling and filling to permit the installation of an effective system.

D. Components

1. Waste management system - 312
2. Waste storage structure - 313
3. Critical area planting - 342
4. Dike - 356
5. Waste treatment lagoon - 359
6. Diversion - 362
7. Fencing - 382
8. Grassed waterway or outlet - 412
9. Waste storage pond - 425
10. Irrigation system, sprinkler - 442
11. Roof runoff management - 558
12. Roofing for runoff control - 559 (limited use)
13. Subsurface drain - 606
14. Surface Drain, field ditch - 607
15. Surface drain, main or lateral - 608
16. Waste utilization - 633

BMP-3 STRIPCROPPING SYSTEMS

A. Purpose To establish a contour, field stripcropping, or similar system to protect soil from wind and water erosion and to prevent the pollution of water from agricultural non-point sources.

B. Applicability To cropland subject to erosion or soil movement which constitutes a water pollution hazard.

C. Description The practice consists of the establishment of stripcropping and, if necessary, the removal of such obstacles as stone walls or hedgerows where applicable. Typical considerations on row crops include keeping crop stubble or residue on the land during winter, establishment of a winter cover crop, and use of adequate protective tillage operations. For contour stripcropping systems, cultural operations must be performed as nearly as practicable on the contour.

D. Components

1. Obstruction removal - 500
2. Stripcropping, contour - 585
3. Stripcropping, field - 586
4. Stripcropping, wind - 589

BMP-4 TERRACE SYSTEMS

A. Purpose To provide control of erosion on cropland and prevent pollution of water from non-point sources.

B. Applicability To cropland subject to erosion from water runoff which constitutes a water pollution problem.

C. Description The practice consists of the installation of terraces, the necessary leveling and filling to permit installation of an effective system, and if necessary, the removal of stone walls or hedgerows in order to permit installation of an effective system. Also included in these systems are underground pipe outlets, other mechanical outlets, vegetative protective outlets and waterways. These systems are usually installed for long periods of time - 10 years or so.

D. Components

1. Obstruction removal - 500
2. Terrace - 600
3. Subsurface drain - 606
4. Underground outlet - 620

BMP-5 DIVERSION SYSTEM

A. Purpose To control erosion, and prevent pollution of water from non-point sources.

B. Applicability To farmland subject to erosion from excess surface or subsurface water where the problem creates a water pollution hazard.

C. Description Diversion systems include ditches, diversions, dikes or subsurface drains. Can be used for erosion control on areas on sloping farmland where the internal water seeps to the surface and causes the land or conservation cover to lose its stability. Often involves the installation of structures such as pipes, chutes, underground outlets or other outlets, if needed, for proper functioning to a ditch or dike, for more even flow or to protect outlets from erosion. Leveling and filling may be necessary to permit installation of an effective system. Also removing portions of stone walls or hedgerows may be necessary to permit establishment of the practice.

D. Components

1. Dike - 356
2. Diversion - 362
3. Obstruction removal - 500
4. Subsurface drain - 606
5. Underground outlet - 620

BMP-6 GRAZING LAND PROTECTION SYSTEM

A. Purpose To protect vegetative cover or make practicable the use of the land for vegetative cover so as to control soil erosion and to prevent the pollution of water from agricultural or silvicultural non-point sources.

B. Applicability To installations that improve water quality by providing water at locations which will prevent water pollution.

C. Description These systems can include:

1. Construction or deepening of wells
2. Development of springs or seeps including fencing of the area, if needed, to protect the development from pollution by livestock
3. Dugouts
4. Installation of pipelines, water storage facilities, cisterns and artificial watersheds
5. Fencing

D. Components

1. Pond - 378
2. Fencing - 382
3. Pipeline - 516
4. Pond sealing or lining - 521
5. Spring development - 574
6. Trough or tank - 614
7. Well - 642

BMP-7 WATERWAY SYSTEM

A. Purpose To prevent erosion and the pollution of water on land from agricultural non-point sources.

B. Applicability To farmland needing permanent sod waterways to safely convey excess surface runoff water in a manner that will prevent water pollution.

C. Description This practice includes site preparation, grading, shaping, filling, and establishing permanent vegetation for waterways. Often subsurface drains may be necessary for proper functioning of a waterway. These are long term, usually 10 years or more, installations.

D. Components

1. Fencing - 382
2. Grassed waterway or outlet - 412
3. Lined waterway or outlet - 468
4. Subsurface drain - 606

BMP-8 CROPLAND PROTECTIVE SYSTEM

A. Purpose To establish vegetative cover for protection from erosion and to prevent pollution of water from agricultural non-point sources.

B. Applicability To cropland subject to severe erosion between crops where erosion constitutes a significant water pollution problem.

C. Description This practice includes the establishment of cover crops and field windbreaks, where necessary.

D. Components

1. Conservation Cropping System - 328
2. Cover and green manure crop - 340
3. Field windbreaks - 392

BMP-9 CONSERVATION TILLAGE SYSTEMS

A. Purpose To reduce pollution from sediment and chemically contaminated runoff, protect soil from wind and water erosion, and improve soil permeability. To reduce water pollution from agricultural non-point sources.

B. Applicability To cropland needing erosion or sediment control that constitutes a significant water pollution problem.

C. Description The conservation tillage practice includes protecting the land involved by crop residue, temporary cover, or other permitted management methods from harvest until the next planting. Tillage operations may consist of:

1. Chisel plowing with other limited operations, or
2. Plow-plant, or
3. Light tillage without plowing, or
4. Approved slot and strip tillage operations ahead of planter, or
5. Planting on chemically killed sods, or
6. Other similar methods.

Chemicals used in performing this practice must be federally and state registered and must be applied strictly in accordance with authorized registered uses, directions on the label and other federal, state, or local policies and requirements.

D. Components

1. Conservation cropping system - 328
2. Conservation tillage system - 329
3. Contour farming - 330

BMP-10 STREAM PROTECTION SYSTEM

A. Purpose To control erosion and prevent the pollution of the water from agricultural non-point sources.

B. Applicability To specific problem areas on small streams or lakes located on or adjacent to farmland where the bank runoff containing sediment, pesticides, or fertilizer constitutes a significant water pollution hazard.

C. Description This practice includes the following:

1. Installation of permanent fencing to protect banks from damage by domestic livestock.
2. Planting trees, shrubs and perennial grass cover as filter strips or buffer zones along banks.
3. Providing access to water for livestock.
4. Installation of livestock crossings that will retard sedimentation and pollution.

D. Components

1. Channel vegetation - 322
2. Fencing - 382
3. Filter strip - 393
4. Streambank protection - 580
5. Tree planting - 612

BMP-11 PERMANENT VEGETATIVE COVER ON CRITICAL AREAS

A. Purpose To control erosion and prevent pollution of water from sediment of agricultural or silvicultural origin.

B. Applicability To critical areas (such as gullies, banks, privately owned roadsides, field borders, and similar problem areas) on farms which are susceptible to erosion and where runoff carrying substantial amount of sediment which constitutes a significant water pollution hazard.

C. Description This practice includes the installation of measures needed to stabilize a source of sediment such as grading, shaping, and filling, the establishment, including minerals, or grasses, trees, or shrubs, and similar measures. These measures are designed to significantly reduce erosion and maintain, or improve the quality of water in a stream, lake, pond, or other water resource.

D. Components

1. Critical area planting - 342
2. Fencing - 382
3. Field borders - 386
4. Filter strip - 393
5. Livestock exclusion - 472
6. Mulching - 484
7. Spoilbank spreading - 572
8. Tree planting - 612

BMP-12 SEDIMENT RETENTION, EROSION, OR WATER CONTROL STRUCTURES

A. Purpose To control erosion and prevent the pollution of water from agricultural or silvicultural non-point sources.

B. Applicability To specific problem areas on farms where runoff of substantial amounts of sediment or runoff containing pesticides or fertilizers constitutes a significant water pollution hazard.

C. Description This practice includes the installation of sediment detention or retention structures such as erosion control dams (excluding water storage dams), desilting reservoirs, sediment basins, debris basins, or similar structures. Channel linings, chutes, drop spillways, and pipe drops that dispose of excess water would also be included as would fencing a vegetative cover, including mulching needed to protect the structure, and leveling and filling to permit the installation of the structure.

D. Components

1. Sediment basin - 350
2. Dike - 356
3. Fencing - 382
4. Grade stabilization structure - 410
5. Structure for water control - 587
6. Water and sediment control basin - 638

BMP-13 IMPROVING AN IRRIGATION SYSTEM AND/OR WATER MANAGEMENT SYSTEM

A. Purpose To improve water quality by preventing or reducing the pollution of water or land from agricultural non-point sources.

B. Applicability To farmland that is currently under irrigation for which an adequate supply of suitable water is available, on which irrigation will be continued and on farmland with a critical area or source that significantly contributes to the water quality problem.

C. Description This practice includes the following measures if included in a plan or portion of a plan for reorganizing an irrigation system:

1. Permanently installed irrigation systems.
2. Lining irrigation ditches.
3. Tailwater recovery systems or other installations for the conservation of soil or water where needed as an integral part of the irrigation system being reorganized.

Some of the items expected to be installed in these systems include installing subsurface drains, open drains, protective outlet structures or similar structures; spreading and sodding or seeding spoil banks resulting from an installation; and necessary site preparation.

There are situations where this BMP, installed for water quality purposes would not be authorized, such as:

1. If the result would be to increase the acreage of cropland on the farm.
2. To drain Wetland Types 3 through 20, as described in the U.S. Department of the Interior, Fish and Wildlife Service Circular 39 (1956).
3. If the sole purpose is for draining of land with a high water table.

D. Components

1. Irrigation water conveyance - 428
2. Pipeline - 430
3. Irrigation system, drip - 441
4. Irrigation system, sprinkler - 442
5. Irrigation system, tailwater recovery - 447
6. Irrigation water management - 449
7. Structure for water control - 587
8. Subsurface drain - 606
9. Surface drain, field ditch - 607
10. Surface drain, main or lateral - 608
11. Underground drain - 620

BMP-14 TREE PLANTING

A. <u>Purpose</u> To improve water quality by planting trees or shrubs to treat critical areas or sources contributing to water pollution.

B. <u>Applicability</u> To farmland subject to water erosion to be established in trees or shrubs to prevent water pollution.

C. <u>Description</u> Included in this practice are:

1. The establishment of a plantation that will provide both forest products and improved protection from wind or water erosion.
2. Clearing land occupied largely by scrubby brush of no economic value where necessary to permit planting desirable tree species.
3. Installing permanent fences, excluding boundary and road fences, needed to protect the plantings from grazing.

Planting orchard trees, and plantings for ornamental purposes, or for Christmas tree production are not included in this practice.

Other considerations include:

1. Planting must be protected from destructive fire and destructive grazing.
2. Chemicals used in performing this practice must be federally and state registered and must be strictly applied in accordance with authorized uses, directions on the label, and other federal, state or local policies and requirements.

D. <u>Components</u>

1. Fencing - 382
2. Cover and green manure crop - 340
3. Tree planting - 612
4. Woodland direct seeding - 652
5. Woodland site preparation - 490
6. Critical area planting - 342

BMP-15 FERTILIZER MANAGEMENT

A. <u>Purpose</u> To improve water quality through needed changes in the fertilizer rate, time, or method of application to achieve the desired degree of control of nutrient movement in critical areas contributing to water pollution.

B. <u>Applicability</u> To farmland where nutrient movement constitutes a significant water pollution problem.

C. <u>Description</u> Factors to be considered in this practice include:

1. Fertilizer application should be based on a current soil test, which is one taken the last 12 months.
2. Fall application of nitrogen on sandy soil should be avoided.
3. A winter cover crop should be established where needed.

D. Components

1. Fertilizer management - 384
2. Waste utilization - 633

BMP-16 PESTICIDE MANAGEMENT

A. Purpose To improve water quality by reducing pesticide use to a minimum and manage pests in critical areas to achieve the desired level of chemicals contributing to water pollution.

B. Applicability To cropland where pesticide use constitutes a significant water pollution problem.

C. Description Chemicals used in performing this practice must be federally, state and locally registered and must be applied strictly in accordance with authorized registered uses, direction on the label and other federal or state policies and requirements. Much information is needed in order to apply these substances in a safe manner in suitable locations.

D. Components

1. Pesticide management - 514

APPENDIX C: BIBLIOGRAPHY

APPENDIX C

BIBLIOGRAPHY

Ackerman, M.T., Queen Lake Water Quality Study, Water Quality and Research Section, Mass. Division of Water Pollution Control, Mass. DEQE, Westborough, Mass., May 1980.

Arnold, James M. and Jeffrey B. Smith, Webster Lake Water Quality Study 1975-1976, Central Mass. Regional Planning Commission & Mass. Division of Water Pollution Control, Water Quality and Research Section, Mass. DEQE, Westborough, Mass., Nov. 1980.

Ashraf, M., R.L. Christensen, and G.E. Frick, The Impact on Dairy Farm Organization of Alternative Manure Disposal Systems: A Method of Assessing the Cost of Environmental Regulation, Bulletin No. 608, Mass. Agricultural Experiment Station, College of Food and Natural Resources, Univ. of Mass., Amherst, Mass., May 1974.

Bailey, Mark R., Lisa J. Rosenberger, and Michael R. Kolman, with Mary Lee Rhodes and Vivian M. Brady, Massachusetts Agricultural Viability Study, USDA, Economic Service, Soil Conservation Service & Forest Service in cooperation with the Mass. Dept. of Food & Agriculture and the Mass. Agricultural Experiment Station, December 1982.

Bear, F.E., Chemistry of the Soil, 2nd edition, New York, Reinhold Publishing Corp., 1964.

Berkshire County Regional Planning Commission, Water Quality Management Plan for the Upper Housatonic River Final Plan/Environmental Impact Statement, for U.S. Environmental Protection Agency, Pittsfield, Mass., Sept. 1978.

Bingham, David R. and Tsuan Hua Feng, Mathematical Modelling of Recovery of a Eutrophic Lake, Report No. Env. E. 65-80-1 for Division of Water Pollution Control, Mass. Water Resources Commission, by Environmental Engineering Program, Dept. of Civil Engineering, Univ. of Mass., Amherst, Mass., Dec. 1980.

Bliven, L.F., E.J. Humenik, F.A. Koehler, and M.R. Overcash, Monitoring Areawide Rural Water Quality, Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 105, No. EE1, Proc. Paper 14343, Feb. 1979, pp. 101-112.

Brackley, R.A., W.B. Fleck, and W.R. Meyer, Hydrology and Water Resources of the Neponset and Weymouth River Basins, Massachusetts, Hydrologic Investigations Atlas HA-484, prepared in cooperation with the Mass. Water Resources Commission, U.S. Geological Survey, Washington, D.C., 1973.

Brackley, R.A. and Bruce P. Hansen, Water Resources of the Nashua and Souhegan River Basins, Massachusetts, Hydrological Investigations Atlas HA276, prepared in cooperation with the Mass. Water Resources Commission, U.S. Geological Survey, 1977.

Cape Cod Planning and Economic Development Commission, Environmental Impact Statement and 208 Water Quality Management Plan for Cape Cod, Volumes 1 and 2, for U.S. Environmental Protection Agency, Barnstable, Mass., Sept. 1978.

Central Massachusetts Regional Planning Commission, Areawide Water Quality Management Plan, for U.S. Environmental Protection Agency, Worcester, Mass., April 1980.

Chesebrough, E.W. and A.J. Screpetis, Baseline Water Quality Surveys of Selected Lakes and Ponds in the Housatonic River Basin, Berkshire County (1974), Water Quality Section, Mass. Division of Water Pollution Control, Mass. DEQE, Westborough, Mass., Sept. 1975.

______, Lake Mattawa Water Quality Study, April 1975-April 1976, Water Quality and Research Section, Mass. Division of Water Pollution Control, Mass. DEQE, Westborough, Mass., May 1978.

______, Pontoosuc Lake Water Quality Study, April 1975-April 1976, Water Quality and Research Section, Mass. Division of Water Pollution Control, Mass. DEQE, Westborough, Mass., April 1978.

______, Quaboag and Quacumquasit Ponds, Water Quality Study, April 1974-April 1975, Mass. Division of Water Pollution Control, Water Quality and Research Section, Westborough, Mass., Feb. 1976.

______, Waushakum Pond Water Quality Study, April 1975-April 1976, Water Quality and Research Section, Mass. Division of Water Pollution Control, Mass. DEQE, Westborough, Mass., August 1977.

Chesebrough, E.W., A.J. Screpetis, and P.M. Hogan, Baseline Water Quality Surveys of Selected Lakes and Ponds in the French and Quinebaug River Basin, 1976, Mass. DEQE Division of Water Pollution Control, Water Quality and Research Section, Westborough, Mass., Nov. 1976.

______, Baseline Water Quality Surveys of Selected Lakes and Ponds in the Housatonic River Basin, Berkshire County, 1976, Water Quality and Research Section, Mass. Division of Water Pollution Control, Westborough, Mass., Dec. 1976.

______, Indian Lake Water Quality Study, 1975 and 1976, Water Quality and Research Section, Mass. Division of Water Pollution, Mass. DEQE, Westborough, Mass., Dec. 1978.

Connecticut Council on Soil and Water Conservation, Agricultural Portion of the Connecticut Areawide Waste Treatment Management Planning Program, Project Report, Oct. 1979.

Curley, John R., Robert P. Lawton, David K. Whittaker, and John M. Hickey, A Study of the Marine Resources of Wellfleet Harbor, Monograph Series No. 12, Division of Marine Fisheries, Dept. of Natural Resources, Commonwealth of Mass., April 1972.

Davey, William B., Conservation Districts and 208 Water Quality Management, prepared by the National Association of Conservation Districts under Environmental Protection Agency Grant No. T90057401-0, June 1977.

Delaney, David F., Groundwater Hydrology of Martha's Vineyard, Massachusetts, Hydrologic Investigations Atlas HA-168, prepared in cooperation with Mass. Water Resources Commission, U.S. Geological Survey, 1980.

Delaney, David F. and Anthony Maevsky, Distribution of Aquifers, Liquid-waste Impoundments and Municipal Water Supply Sources, Massachusetts, Water Resources Investigations Open File Report 80-431, prepared in cooperation with the Mass. Dept. of Environmental Quality Engineering, U.S. Geological Survey, Boston, MA, 1980.

Deubert, Karl H., Impact of the Cranberry Industry on the Quality of Groundwater in the Cape Cod Area, Publication No. 42, Water Resources Research Center, Univ. of Mass., Amherst, Mass.

Doyle, R.C., G.C. Stanton, and D.C. Wolf, Effectiveness of Forest and Grass Buffer Strips in Improving the Water Quality of Manure Polluted Runoff, American Society of Agricultural Engineers, Paper No. 77-2501, St. Joseph, Michigan, Dec. 1977.

Feng, Tsuan H., Control of Benthic Deposits in Lakes, Publication No. 16, Water Resources Research Center, Univ. of Mass., Amherst, Mass., July 1971.

Fiske, John D., John R. Curley, and Robert P. Lawton, A Study of the Marine Resources of the Westport River, Monograph Series Number 7, Division of Marine Fisheries, Dept. of Natural Resources, Commonwealth of Mass., May 1968.

Frimpter, Michael H., Groundwater Availability in the North Part of the Connectcut Valley Urban Area, Central New England, Miscellaneous Investigation Series MAP I-1074-1, U.S. Geological Survey, 1980.

Furfari, Santo A., Training Course Manual, Nonpoint Pollution in Shellfish Sanitation, Northeast Technical Services Unit, Shellfish Sanitation Branch, U.S. Public Health Service, Food and Drug Administration, Dept. of Health, Education and Welfare, 1979.

Gay, Frederick B. and David F. Delaney, Hydrology and Water Resources of the Lower Merrimack River Basin, Massachusetts, from Concord River, Lowell to Plum Island, Newburyport, Hydrologic Investigations Atlas HA-616, prepared in cooperation with Mass. Water Resources Commission, U.S. Geological Survey, 1980.

Gay, F.B., L.G. Toler, and B.P. Hansen, Hydrology and Water Resources of the Deerfield River Basin, Massachusetts, Hydrologic Investigations Atlas HA-506, prepared in cooperation with the Mass. Water Resources Commission, U.S. Geological Survey, Washington, D.C., 1974.

Gilbertson, C.B., et al., Animal Waste Utilization on Cropland and Pastureland: A Manual for Evaluating Agronomic and Environmental Effects, Office of Development and Research, E.P.A., USDA Utilization Research Report No. 6 and EPA-600/2-79-059, Ada, Oklahoma, October 1979.

Guest, R.W., S.D. Klausner, and R.P. March, 1973 Guidelines for Dairy Manure Management in New York State, Agricultural Engineering Extension Bulletin 400, Dept. of Agricultural Engineering, New York State College of Agriculture and Life Sciences, Cornell Univ., Ithaca, N.Y.

Haith, Douglas and Raymond C. Loehr, Effectiveness of Soil and Water Conservation Practices for Pollution Control, EPA-600/3-79-106, Environmental Research Lab., Office of research and Development, U.S. Environmental Protection Agency, Athens, Georgia, Oct. 1979.

Hansen, Bruce P., L.G. Toler and Frederick B. Gay, Hydrology and Water Resources of the Hoosic River Basin, Massachusetts, Hydrologic Investigations Atlas HA-481, prepared in cooperation with the Massachusetts Water Resource Commission and Berkshire County, U.S. Geological Survey, 1973.

International Reference Group on Great Lakes Pollution from Land Use Activities, PLUARG, Environmental Management Strategy for the Great Lakes System, Windsor, Ontario, July 1978.

Jerome, William C., Jr., Arthur P. Chesmore, and Charles O. Anderson, Jr., A Study of the Marine Resources of Quincy Bay, Monograph Series No. 2, Division of Marine Fisheries, Dept. of Natural Resources, Commonwealth of Mass., March 1966.

______, A Study of the Marine Resources of the Annisquam River-Gloucester, Harbor Coastal System, Monograph Series No. 8, Division of Marine Fisheries, Dept. of Natural Resources, Commonwealth of Mass., Dec. 1969.

Jerome, William C., Arthur P. Chesmore, Charles O. Anderson, Jr., and Frank Grice, A Study of the Marine Resources of the Merrimack River Estuary, Monograph Series, Number 1, Division of Marine Fisheries, Dept. of Natural Resources, Commonwealth of Mass., June 1965.

Kennebec County Soil and Water Conservation District, Watershed Plan, Lovejoy Pond Watershed, Kennebec County, Maine, with assistance from USDA, Soil Conservation Service, Orono, Maine, April 1981.

Kennebec Soil and Water Conservation District, Webber Pond Watershed Project Application, Augusta, Maine, February 1982.

Knisel, Walter G., editor, CREAMS: A Field-scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, U.S. Department of Agriculture, Conservation Research Report No. 26, 1980.

Kortman, R.W., D.D. Henry, A. Kuether and S. Kaufman, Epilimnetic Nutrient Loading by Metalimnetic Erosion and Resultant Algal Responses in Lake Waramaug, Connecticut, Lake Waramaug Task Force - NWCRPA Warren, CT, 1981.

Ku, Wen-Chi and Tsuan Hua Feng, Equilibrium Adsorption of Inorganic Phosphate by Lake Sediments, Contract Number MDWPC 73-07(3) for Division of Water Pollution Control, Mass. Water Resources Commission, Environmental Engineering Program, Dept. of Civil Engineering, Univ. of Mass., Amherst, Mass., Jan. 1975.

Lake, James and James Morrison, Environmental Impact of Land Use on Water Quality, Final Report on the Black Creek Project, in two volumes - Technical Report and Summary, prepared for U.S. Environmental Protection Agency by Allen County Soil and Water Conservation District and USDA, SCS and ARS and Purdue Univ. and Univ. of Illinois, EPA-905/9-77-007A and B, Oct. 1977.

Lake Waramaug Task Force, Northwestern Connecticut Regional Planning Agency, Lake Waramaug Watershed Management Plan, 1978, Warren, CT.

Larsen, D.P. and H.T. Mercier, Lake Phosphorus Loading Graphs: An Alternative, Eutrophication and Lake Restoration Branch Working Paper No. 174, Corvallis Environmental Research Laboratory, Corvallis, Oregon, July 1975.

Lee, G.F., R.A. Jones, and W. Rast, "Availability of Phosphorus to Phytoplankton and Its Implications for Phosphorus Management Strategies, Chapter 11," Phosphorus Management Strategies for Lakes, Proceedings of the 1979 Conference, edited by R.G. Luehr, C.S. Martin, W. Rast, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1980.

Light, Robert G., Handling Liquid Wastes from Milking Centers, Cooperative Extension Service, Univ. of Mass., Amherst, Mass.

Likens, G.E., F.H. Bormann and J.S. Eaton, "Variations in Precipitation and Stream-Water Chemistry at the Hubbard Brook Experimental Forest During 1964 to 1977." Effects of Acid Precipitation of Terrestrial Ecosystems, edited by T.C. Hutchinson and M. Haras, Plenum Publishing Corp., 1980, pp. 443-464.

Likens, G.E. and O.L. Loucks, "Analysis of Five North American Lake Ecosystems III. Sources, Loading and Fate of Nitrogen and Phosphorus." Verh. International Verein. Limnology, Vol. 20, September 1978, pp. 568-573.

Loehr, Raymond C. et al., Best Management Practices for Agriculture and Silviculture, Proceedings of the 1978 Cornell Agricultural Waste Mangement Conference, Ann Arbor Science Publishers, Inc., Ann Arbor, Mich, 1979.

Lower Pioneer Valley Regional Planning Commission, Inventory of Potential Water Pollution Sources for Lower Pioneer Valley, Draft, Funded by a grant from Environmental Protection Agency under PL 92-500, Section 208, West Springfield, Mass., August 1978.

Ludlam, S.D., The Recent History of Productivity in Selected Berkshire Lakes, Publication No. 90, Water Resources Research Center, Univ. of Mass., Amherst, Mass., Sept. 1977.

______, The Relationship Between Water Depth and Sedimentary Pigment Concentration in Two Holomictic Berkshire Lakes, Publication No. 105, Water Resources Research Center, Univ. of Mass., Amherst, Mass., June 1979.

Ludlam, S.D., K.S. Hutchison and G.E. Henderson, The Limnology of Stockbridge Bowl, Stockbridge, Massachusetts, Completion Report FY-73-4, Water Resources Research Center, Univ. of Mass., Amherst, Mass.

Lycott Environmental Research, Inc., A Comprehensive Eutrophication, Study of Lake Lashaway, East and North Brookfield, Massachusetts, prepared for East Brookfield Conservation Commission, North Brookfield Conservation Commission, Southbridge, Mass.

Martha's Vineyard Commission, Final Plan, E.I.S., Water Quality Management Plan for Martha's Vineyard. Final Plan/Environmental Impact Statement for U.S. Environmental Protection Agency, April 1978.

Maryland State Soil Conservation Committee, Soil Conservation and Water Quality Plan, with the assistance of USDA, Soil Conservation Service, Annapolis, MD, Nov. 1979.

Massachusetts Department of Environmental Quality Engineering, Clean Lakes Program, Rules and Regulations, General Application and Administration, 1982, Boston, Mass.

Massachusetts Department of Environmental Quality Engineering, Planning Office, Final Water Quality Management Plan for Nantucket, Boston, Mass., Dec. 1979.

_____, Water Quality Management Plan for Central Massachusetts (non-designated areas), Boston, Mass., December 1979.

_____, Water Quality Management Plan for Ashburnham, Gardner, Hubbardston, Templeton, and Winchendon, Boston, Mass., January 1980.

_____, Water Quality Management Plan for the Elizabeth Islands, Boston, Mass., Dec. 1979.

Massachusetts Division of Fisheries and Game, Progress Reports on Pesticides Monitoring in Massachusetts April 1971-March 1973, Research and Demonstration Project 70-09, for Mass. Division of Water Pollution Control.

Massachusetts Division of Water Pollution Control, Housatonic River Basin 1975 Water Quality Management Plan, Water Quality Section, Mass. Dept. of Environmental Quality Engineering, Westborough, Mass., Dec. 1975.

_____, Technical Services Branch, Baseline Water Quality Studies of Selected Lakes and Ponds in the Taunton River Basin, 1975, 1979, and 1980, Mass. Dept. of Environmental Quality Engineering, Westborough, Mass., Jan. 1982.

_____, Chicopee River Basin, 1980 Water Quality Data and Wastewater Discharge Data, Mass. Department of Environmental Quality Engineering, Westborough, Mass., Feb. 1981.

_____, The Housatonic River, Water Quality Management Plan 1981, Mass. Dept. of Environmental Quality Engineering, Westborough, Mass., Nov. 1981.

Massachusetts Division of Water Pollution Control, Water Quality Management Section, Chicopee River Basin Report, Ware, Swift, Quaboag, and Chicopee Rivers, Part A, Data Record on Water Quality, Mass. Water Resources Commission, Boston, Mass., May 1972.

Massachusetts Division of Water Pollution Control, Water Quality and Research Section, The Assabet River, 1979, Water Quality Data, Mass. Dept. of Environmental Quality Engineering, Westborough, Mass., Nov. 1979.

_____, Directory of Massachusetts Lake and Pond Associations, Mass. DEQE, Westborough, Mass., Jan 1980.

_____, Lake Cochituate Water Quality Data, April 1976-April 1977, Mass. DEQE, Westborough, Mass., Dec. 1977.

_____, Massachusetts Lake Classification Program, Mass. DEQE, Westborough, Mass., revised Jan 1980.

_____, Merrimack River Basin 1979 Water Quality Survey Data, Wastewater Discharge Data, Nonpoint Source Sampling Data, Mass. DEQE, Westborough, Mass., Sept. 1980.

_____, The Upper Quaboag River Basin, Dunn Brook - Seven Mile River, 1979 Water Quality Data, Mass. DEQE, Westborough, Mass., Sept. 1979.

Massachusetts Division of Water Pollution Control, Mass. Water Resources Commission, Massachusetts Water Quality Standards, Sept. 15, 1978, Commonwealth of Massachusetts, Sept. 1978.

______, Water Quality Section, Deerfield River, 1973 Water Quality Survey Data, Mass. Water Resources Commission, Westborough, Mass., 1973.

______, Housatonic River, 1974 Water Quality Survey Data, Massachusetts Water Resources Commission, Westborough, Mass.

Massie, L.R., R.D. Powell, and R.E. Graves, "Land Application of Manures--Wisconsin's Manure Management Plan," International Symposium on Livestock Wastes, Urbana, Illinois, April 21-24, 1975.

McElroy, A.D., S.Y. Chiu, J.W. Nebgen, A. Aleti, and F.W. Bennett, Loading Functions for Assessment of Water Pollution from Nonpoint Sources, EPA-600/2-76-151, Office of Air, Land, and Water Use, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C., May 1976.

McVoy, R.S., P.W. Vernon, Lake Winthrop, 1978-1979 Water Quality Study, Water Quality and Research Section, Massachusetts Division of Water Pollution Control, Mass. D.E.Q.E., Westborough, Mass., April 1980.

Merrimack Valley Planning Commission, Final Water Quality Status Report for the Merrimack Valley Region, for U.S. Environmental Protection Agency, Haverhill, Mass., June 1979.

Metropolitan Area Planning Council, Draft Environmental Impact Statement and Draft Areawide Waste Treatment Management Plan for the Metropolitan Area Planning Council, Part 1, Volumes 1, 11, and 111, and Part 2, for U.S. Environmental Protection Agency, Boston, Mass., April 1978.

Meyer, Judy L., "The Role of Sediments and Bryophytes in Phosphorus Dynamics in a Headwater Stream Ecosystem," Limnological Oceanography, Vol. 24, No. 2, 1979, pp. 365-375.

Meyer, J.L. and G.E. Likens, "Transport and Transformation of Phosphorus in a Forest Stream and Ecosystem," Ecology, Vol. 60, No. 6, 1979, pp. 1255-1269.

Meyer, J.L., G.E. Likens, and J. Sloane, "Phosphorus, Nitrogen and Organic Carbon Flux in a Headwater Strream," Archives of Hydrobiology, Stuttgart, Marz, 1981, pp. 28-44.

Montachusett Regional Planning Commission, Montachusett-Nashua Areawide Water Quality Management Program, for the U.S. Environmental Protection Agency, Fitchburg, Mass., Jan. 1979.

Montachusett Regional Planning Commission 208 Program, Legal and Institutional Approaches for the Management of Erosion and Sedimentation in the Montachusett-Nashua Area, for U.S. Environmental Protection Agency, Fitchburg, Mass., August 1977.

New England Crop and Livestock Reporting Service, Massachusetts Agricultural Statistics, Massachusetts Agriculture 1981, for Mass. Department of Food and Agriculture, Concord, New Hampshire and similar annual reports for earlier years.

New York State College of Agriculture and Life Sciences at Cornell University, Cornell Field Crops Handbook, Cornell University, Ithaca, N.Y.

Norvitch, Ralph F., Donald F. Farrell, Felix H. Pauszek, and Richard G. Petersen, Hydrology and Water Resources of the Hoosatonic River Basin, Massachusetts, Hydrologic Investigations Atlas HA-281, prepared in cooperation with the Mass. Water Resources Commission and Berkshire County, U.S. Geological Survey, Washington, D.C., 1968.

Notini, Barbara R. and Ellen M. Chagnon, Lake Attitash Water Quality Study, May 1977-April 1978, Mass. Division of Water Pollution Control, Water Quality and Research Section, Mass. Dept. of Environmental Quality Engineering, Westborough, Mass., May 1980.

Notini, Barbara R. and Judith Morrison, Boons Pond Diagnostic/Feasibility Study, April 1979-July 1980, Mass. Division of Water Pollution Control, Water Quality and Research Section, Westborough, Mass., April 1981.

Ogg, C.W., L.A. Christensen, and R.E. Heimlich, Economics of Water Quality in Agriculture--A Literature Review, ESCS-58, U.S. Department of Agriculture, Economics, Statistics and Cooperative Service, Washington, D.C., July 1979.

Old Colony Planning Council, Land Use/Water Quality Issues in the Old Colony Area, Brockton, Mass.

Omernik, J.M., The Influence of Land Use on Stream Nutrient Levels, Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, PB 251 150, Ecological Research Series, Corvallis, Oregon, Jan 1976.

______, Nonpoint Source--Stream Nutrient Level Relationships--A Nationwide Study, Corvallis Environmental Research Laboratory, Corvallis, Oregon, U.S. Environmental Protection Agency, EPA-600/3-77-105, Sept. 1977.

Rhode Island Statewide Planning Program, Preliminary Draft, Rhode Island Areawide Water Quality Management Plan, prepared under Section 208 Federal Water Pollution Control Act Amendments of 1972, U.S. Environmental Protection Agency, Providence, R.I., Sept. 1978.

Rittall, Walt, Lynn R. Shuyler, et al., Guidelines for Evaluation of Agricultural Nonpoint Source Water Quality Projects, prepared by EPA Interagency Taskforce, U.S. Environmental Protection Agency, Implementation Branch, Water Planning Division, Washington, D.C.

Rose, David and Paul Fischer, Westport River Watershed, Bristol County, Massachusetts, Application for USDA-RCWP Special Project, submitted by Massachusetts State RCWP Development Committee, prepared Agricultural Stabilization and Conservation Service.

Smith, C.H., R.A. Leonard, G.W. Longdale, and G.W. Bailey, Transport of Agricultural Chemicals from Small Upland Piedmont Watersheds, EPA-600/3-78-056, Environmental Research Laboratory, Athens, Georgia, Office of Research and Development, U.S. Environmental Protection Agency, May 1978.

Snow, Phillip D. and Francis A. DiGiano, Mathematical Modeling of Phosphorus Exchange Between Sediments and Overlying Water in Shallow Eutrophic Lakes, Report to Division of Water Pollution Control, Mass. Water Resouces Commission, Dept. of Environmental Quality Engineering, Environmental Engineering Program, Dept. of Civil Engineering, Univ. of Mass., Amherst, Mass., Report No. Env. E. 54-76-3, Sept. 1976.

______, Relationship Between Trophic State and Chemical Parameters in Sediment-Water Systems of Selected Western Massachusetts Lakes, for Division of Water Pollution Control, Mass. Water Resources Commission, Contract No. 15-51452, Environmental Engineering, Dept. of Civil Engineering, Univ. of Mass., Amherst, Mass., Feb. 1973.

Sonzogni, William., et al., "Pollution from Land Runoff," Environmental Science and Technology, Vol. 14, pg. 148-153, American Chemical Society.

Southeastern Regional Planning and Economic Development District, 208 Water Quality Areawide Management Plan for Southeastern Massachusetts, Final Recommendations and Environmental Impact Statement, for U.S. Environmental Protection Agency, Marion, Mass., Feb. 1978.

Special Legislative Commission on Water Supply, Water Quality Task Force, In Cooperation with Dept. of Environmental Quality Engineering, Commonwealth of Mass., Chemical Contamination, Sept. 1979, and In Cooperation with U.S. E.P.A., Region 1.

Stall, J.B. and M.T. Lee, Reservoir Sedimentation and Its Causes in Illinois, Illinois State Water Survey, Urbana, Illinois, Aug. 2, 1978.

State of Maryland, Statewide Agriculture Water Quality Management Program for the Control of Sediment and Animal Wastes, Dept. of Natural Resources, Water Resources Administration, Annapolis, Maryland, Feb. 1979.

Stewart, B.A. et al., Control of Water Pollution from Cropland, Vol. I, A Manual for Guideline Development and Volume II, An Overview, USDA, Agricultural Research Service and Office of Research and Development, Environmental Protection Agency, Report Nos. ARS-H-5-1 and ARS-H-5-2 and EPA-600/2-75-0260 and EPA-600/2-75-0266, Nov. 1975.

Stuart, G. and D. Dunshie, Effects of Timber Harvest on Water Chemistry, White Mountain National Forest, Forest Service, U.S. Department of Agriculture, 1974.

Terrell, Charles R., Editor, 1980/81 Water Quality Summary, Soil Conservation Service, USDA, Soil Conservation Service, Washington, D.C.

Tisdale, S.L. and W.L. Nelson, Soil Fertility and Fertilizers, 2nd Edition, New York, The MacMillan Company, 1966.

Tomlinson, W.E., Jr., Cranberry Insects, Available at the Cranberry Experiment Station, Wareham, Mass.

U.S. Dept. of Agriculture, Economics, Statistics and Cooperatives Service, Forest Service, Soil Conservation Service, Water and Related Land Resources of the Connecticut River Region, Massachusetts, In Cooperation with Mass. Water Resources Commission, August 1978.

______, Soil Conservation Service, Agricultural Waste Management Field Manual, Aug. 1975.

______, Soil Conservation Service, Environmental Impact Statement, Rural Clean Water Program, As Authorized by: Section 208(j) of the Clean Water Act of 1977, Washington, D.C., Aug. 1978.

______, Soil Conservation Service, Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts, Amherst, Mass., Oct. 1975.

______, Soil Conservation Service, Hydrologic Units, Massachusetts, Map and Area Measurements of U.S. Water Resources Council Hydrologic Units and Soil Conservation Service Watershed Codes, July 1981.

______, Soil Conservation Service, Soil Survey Laboratory Data and Descriptions for Some Soils of New England States, Soil Survey Investigations Report No. 20, Aug. 1968.

______, Soil Conservation Service, Study of Nonpoint Agricultural Pollution, SNAP, State of Maine, Sponsored by Maine Soil and Water Conservation Commission, Maine Association of Conservation Districts, Maine Department of Environmental Protection, Maine State Planning Office, Orono, Maine.

______, Soil Conservation Service, Economic Research Service and Forest Service, Water and Related Land Resources of the Berkshire Region, Massachusetts, In Cooperation with Massachusetts Water Resources Commission, 1977.

U.S. Dept. of Commerce, Bureau of the Census, 1978 Census of Agriculture, Volume 1, State and County Data, Part 21, Massachusetts, AC78-A-21, Washington, D.C., March 1981.

U.S. Environmental Protection Agency, Environmental Impact Statement, Wastewater Collection and Treatment Facilities, Nantucket, Massachusetts, Final, Boston, Mass., Aug. 1981.

______, Office of Water Planning and Standards. Clean Lakes and US, EPA-440/5-79-021, Washington, March 1979.

U.S. Geological Survey, Water Resource Data for Massachusetts and Rhode Island, Water Year 1980, U.S. Geological Survey Water Date Report MA-RI-80-1, Prepared In Cooperation with the States of Mass. and R.I. and with other agencies. Water Resource Division, U.S. Geological Survey, Boston, Mass., 1981, and other similar annual reports for earlier years and for adjacent states.

Vaccaro, R.F., et al., Wastewater Renovation and Retrieval on Cape Cod, for Office of Research and Development, U.S. Environmental Protection Agency, Ada, Oklahoma, and in cooperation with Mass. Division of Water Pollution Control, Woods Hole Oceanographic Institute, Woods Hole, Mass.

Van Arsdale, Alan and Michael T. Ackerman, Norton Reservoir Water Quality Study April 1975 - March 1976, Mass. Division of Water Pollution Control, Water Quality and Research Section, Mass. DEQE, Westborough, Mass., July 1980.

Vanderholm, D.H., et al., Livestock Feedlot Runoff Control by Vegetative Filters, EPA-600/2-79-143, U.S. EPA, Office of Research and Development, Ada, Oklahoma, Aug. 1979.

VanDyne, Donald L. and Conrad B. Gilbertson, Estimating U.S. Livestock and Poultry Manure and Nutrient Production, Report No. ESCS-12, Commodity Economics Division, Economics, Statistics and Cooperatives Service, USDA, Washington, D.C., March 1978.

Vollenweider, R.A., W. Rast, and J. Kerekes, "Chapter 9. The Phosphorus Loading Concept and Great Lakes Eutrophication. Phosphorus Management Strategies for Lakes," Proceedings of the 1979 Conference at Cornell Univ., Edited by R.C. Loehr, C.S. Martin, and W. Rast, Ann Arbor Science Publishers, Inc., Ann Arbor, Mich.

Walker, Eugene H., Water Resources of Nantucket Island, Massachusetts, Hydrologic Investigations Atlas, HA-615, prepared in cooperation with the Massachusetts Water Resources Commission, U.S. Geological Survey, 1980.

Walker, Eugene H. and William W. Caswell, Map Showing Availability of Groundwater in the Connecticut River Lowlands, Massachusetts, Hydrologic Investigations Atlas-563, prepared in cooperation with the Mass. Water Resources Commission, U.S. Geological Survey, 1977.

Walter, M.F. et al., Soil and Water Conservation Practices for Pollution Control, Presented at 1977 winter meeting of American Society of Agricultural Engineers, St. Joseph, Mich., Dec. 1977, Paper No. 77-2506.

Westport River RCWP Project Local Coordinating Committee, Rural Clean Water Program, Westport River Watershed Project, Westport, Mass. Plan of Work 1981.

Whittaker, Gayle E., White Island Pond, Water Quality Study, August 1976 - May 1978, Mass. Division of Water Pollution Control, Water Quality and Research Section, Mass. Dept. of Environmental Quality Engineering, Westborough, Mass., June 1980.

Willey, R.E., J.R. Williams, and G.D. Tasker, Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Westport River, Westport to Seekonk, Hydrologic Investigations Atlas HA-275, prepared in cooperation with Mass. Water Resources Commission, U.S. Geological Survey, 1978.

Williams, J.R., D.F. Farrell, and R.E. Willey, Water Resources of the Taunton River Basin, Southeastern Massachusetts, Hydrologic Investigations Atlas HA-460, prepared in cooperation with Mass. Water Resources Commission, U.S. Geological Survey, Washington, D.C., 1973.

Williams, John R. and Gary D. Tasker, Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Northwest Shore of Buzzards Bay, Hydrologic Investigations Atlas HA-560, prepared in cooperation with the Mass. Water Resources Commission, U.S. Geological Survey, 1978.

______, Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Plymouth to Weweantic River, Wareham, Hydrologic Investigations Atlas HA-507, for Massachusetts Water Resources Commission, U.S. Geological Survey, Washington, D.C., 1974.

Winooski Natural Resources Conservation District, Vermont Agency of Environmental Conservation, Vermont Department of Agriculture, USDA Soil Conservation Service and USDA Forest Service, Watershed Plan - LaPlatte River Watershed, Chittenden County, Vermont, July 1979.

Wischmeier, W.H. and D.D. Smith, Predicting Rainfall Erosion Losses - A Guide to Conservation Planning, USDA, Science and Education Administration in cooperation with Purdue Agricultural Experiment Station, Agricultural Handbook No. 537, Washington, D.C., 1978.

Wood, L.W. and C. Barnes, Analysis and Comparison of Northeastern New York State Atmospheric Phosphorus Deposition Rates, New York State Dept. of Health, Albany, N.Y. and Dept. of Chemical and Environmental Engineering, Rensselaer Polytechnic Institute, Troy, N.Y., 1982.

Wright, Raymond M. and Steven A. DeGabriele, Housatonic River 1974 Water Quality Analysis, Mass. Division of Water Pollution Control, Water Quality Section, Mass. Water Resources Commission, Westborough, Mass., May 1975.

 ✰ U.S. GOVERNMENT PRINTING OFFICE: 1984 702-354

U.S.D.A. Soil Conservation Service, Economic Research Service and Forest Service
in cooperation with Massachusetts Department of Environmental Quality Engineering.

MASSACHUSETTS AGRICULTURAL WATER QUALITY STUDY

MAP NO. 26

LIVESTOCK CONCENTRATIONS

ANIMAL UNITS	DAIRY	POULTRY	MIXED
10-25	D-10	P-10	M-10
25-50	D-25	P-25	M-25
50-100	D-50	P-50	M-50
100+	D-100	P-100	M-100

AVERAGE ANNUAL SOIL LOSS (tons/acre/year)

0-1.5 6.1-10.0
1.6-3.0 10.1-20.0
3.1-6.0 20.1+

NOTE 1: CRANBERRY BOG SOIL LOSS 0.0 TONS/ACRE/YEAR

NOTE 2: ANIMAL UNITS & AVERAGE ANNUAL SOIL LOSS SHOWN FOR 49 SELECTED CITIES AND TOWNS

AGRICULTURAL LAND USE

T TILLED
TH HAYFIELD
TRC ROW CROP
TCR CROP ROTATION
CB CRANBERRY BOG
P PASTURE
N NURSERY
O ORCHARD
TCG CLOSE GROWN

WATER RESOURCES

LAKE, POND, RIVER, STREAM

WETLAND

MAJOR AQUIFER - ONLY SHOWN FOR 177 CITIES AND TOWNS OF GENERAL STUDY AREA

... Topographic map 2 Aquifer Information-From U.S. Geological Survey groundwater maps. 3 Land Use and Livestock Information-Developed By SCS in 1980

OCTOBER 1983 4-R-38,457